INTERAVIA

World Review of Aviation and Astronautics
with Electronics Supplement

IN THIS ISSUE

Investment in Space ...First Dividends

Grumman Mohawk Inertial Navigation

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VOLUME XV

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Volume XV

INTERAVIA

November 1960

WORLD REVIEW OF AVIATION AND ASTRONAUTICS

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Front cover: Preparations for a *Thor-Able* launching at Cape Canaveral. Rockets of this type were used, for example, to launch the American planetoid *Pioneer V*.

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The transport of persons and property in absolute safety is the constant concern of the management of the Belgian Air Lines, as indeed it is of any air transport company. The priority of safety over all other considerations is stressed both in the general policy directives issued to the staff and in the establishment and observation of the standards for equipment utilization and the working conditions of aircrews.
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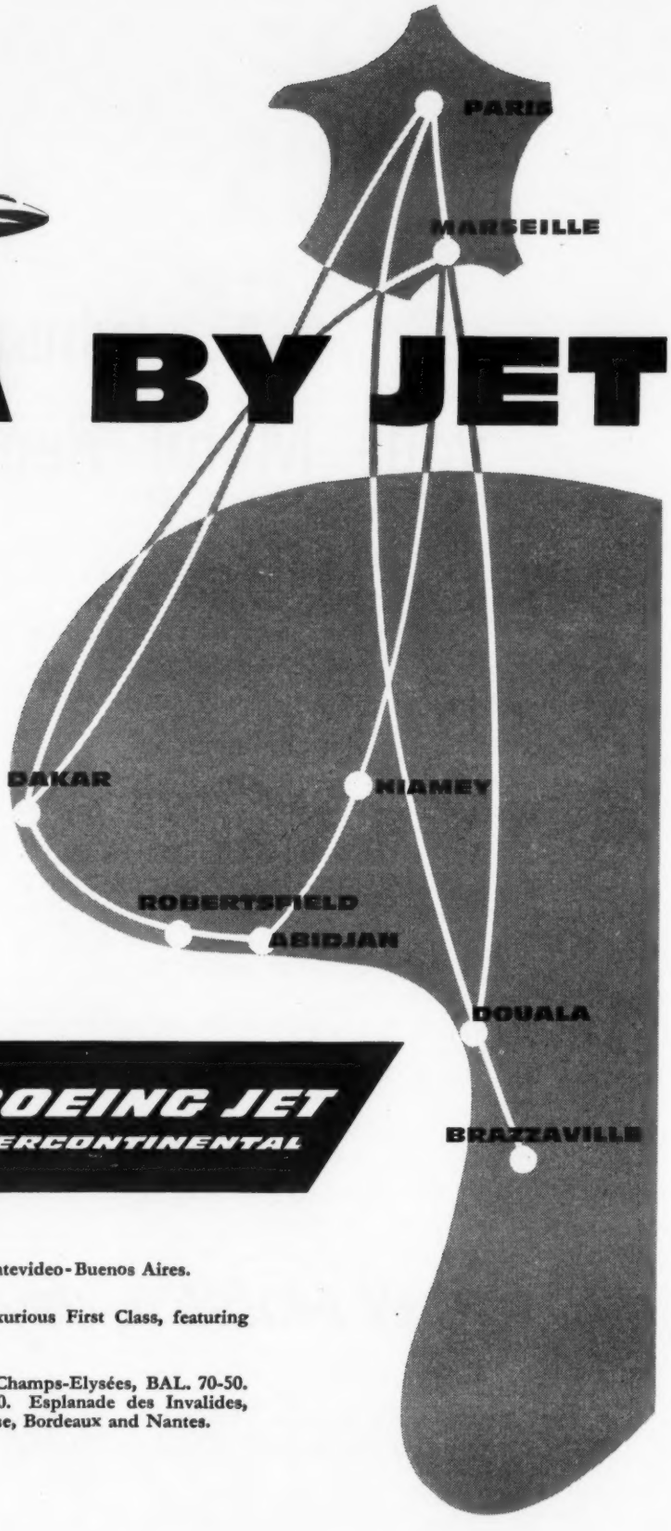

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AIR FRANCE

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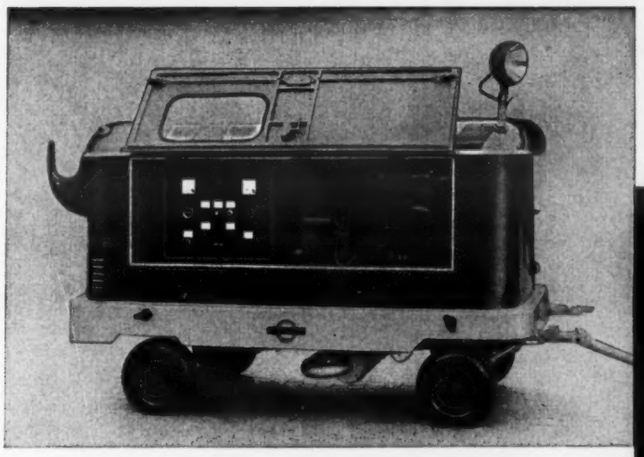

◀ **ROLSTARTER** This equipment is used at many airports in Germany and other countries to start piston-engine aircraft and the VISCOUNT.

JET-ELECTRIC 75 ▶
Self-propelled, diesel-powered equipment for supplying power to the BOEING 707, DC-8 and LOCKHEED ELECTRA requiring 400 c/s three-phase, 120/208 V.

◀ **JET-FREQUENTA**
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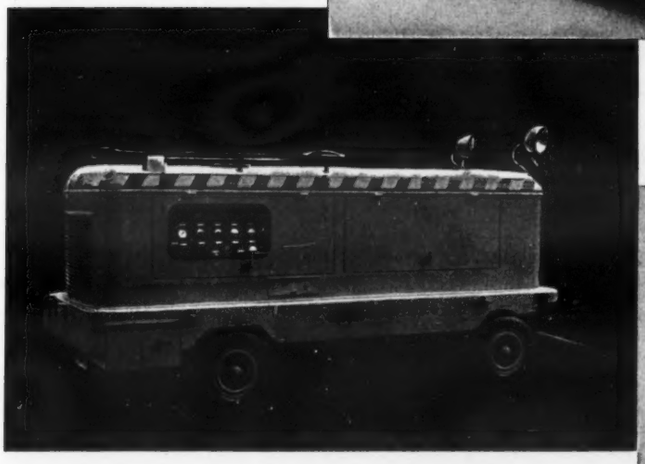
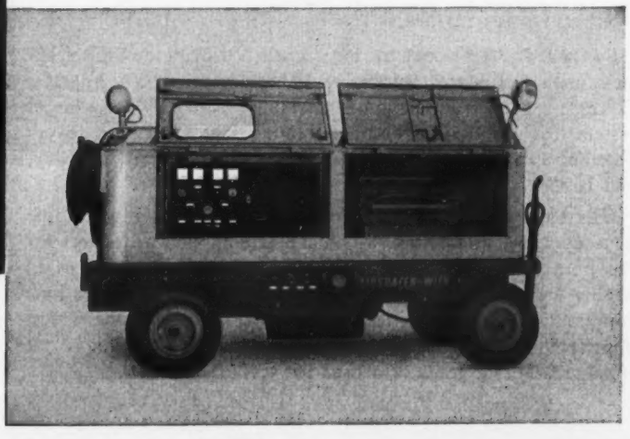


◀ **JET-AIRSTARTER** Diesel compressor unit for compressed air starting of BOEING 707, DC-8 and LOCKHEED ELECTRA aircraft.



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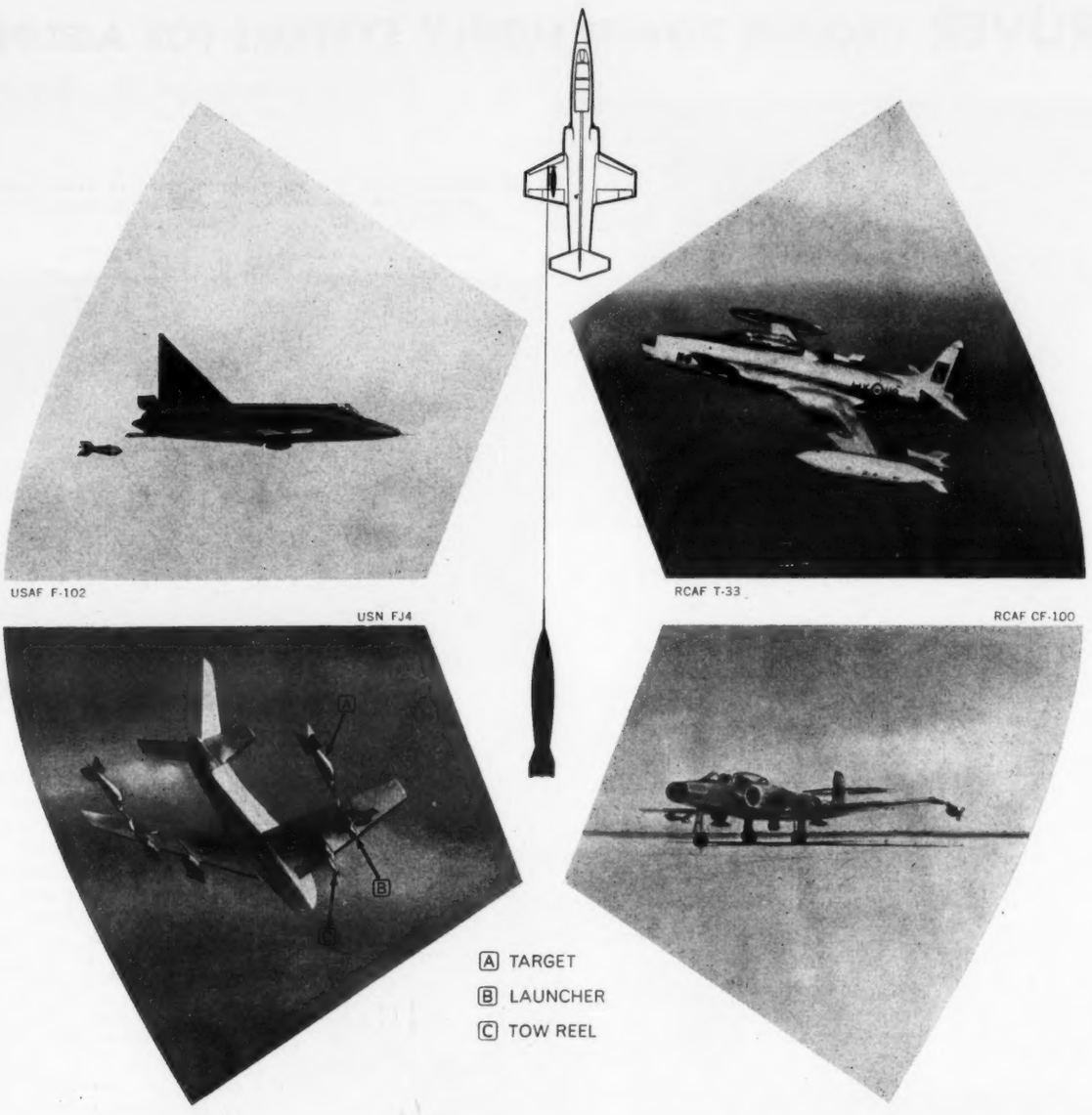

Swedish Air Service, Ltd. Provides High Performance Tow-Target Systems

Swedish Air Service, Ltd. has signed a distributorship agreement with Del Mar Engineering Laboratories of Los Angeles, California to distribute high-performance RADOP® tow-target systems for use in aerial combat training. The agreement covers distribution of this new equipment in Sweden, Denmark, Norway, and Israel.

The basic component of the system is a lightweight subsonic or a supersonic tow target, which can be equipped with flares for the homing of infrared missiles, and with special devices to enable the interceptor pilot to locate the target visually at long ranges. Provision is also made in the target to measure the closest approach of the weapons to the target when a direct hit is not obtained. The target is also used for surface-to-air training.

Tow reels will be provided which hold up to 6½ miles of fine wire tow line, as well as target launchers which carry, launch, and recover the targets in-flight. The equipment is readily installed on, or removed from, operational fighter aircraft.

These inexpensive RADOP weapons training systems, developed by the Del Mar Engineering Laboratories, are already in extensive use by the air services of the United States, Canada, and other NATO nations. Now, the distribution of this equipment by Swedish Air Service, Ltd. will make the procurement and servicing of these systems much more convenient to free world airforces located in Sweden, Denmark, Norway, and Israel.

For more information write Swedish Air Service, Ltd., Arsenalsgatan 4, Stockholm C, Sweden.

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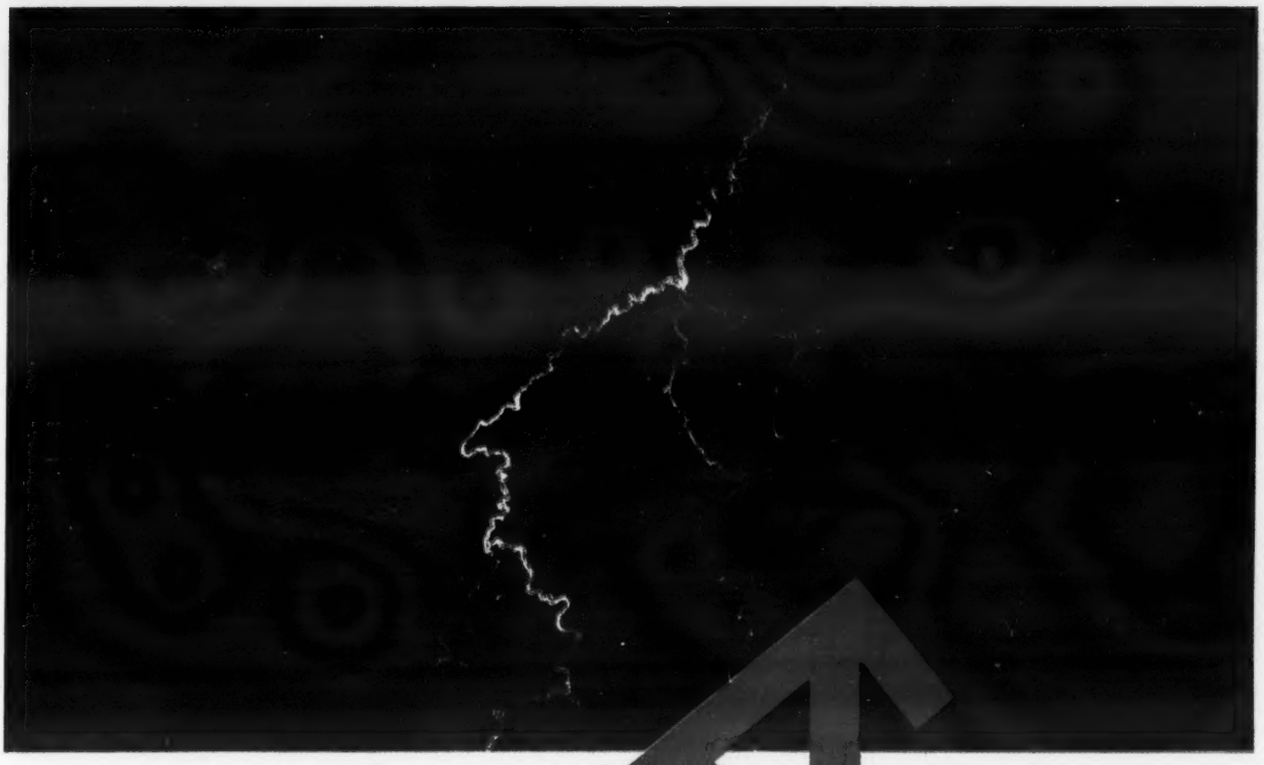

WHATEVER THE WEATHER

the Ryan AN/APN-97 Doppler Navigator for helicopters continuously and automatically detects and displays drift, vertical and heading speeds. By providing sustained automatic hovering and **all-weather** capabilities, it made possible a vital breakthrough in anti-submarine warfare missions. The first, lightest, self-contained navigator of its kind, the APN-97 is in full production for the Navy, Marines and Coast Guard and is the **only** Doppler helicopter navigator in world-wide operational use. The APN-97 operates on the **approved** frequency of 13,300 megacycles and has demonstrated **very high accuracy.** Applications include: All-Weather ASW, Rescue, Navigation, Blind Landings, Automatic Hovering, Aerial Surveys, Drone Helicopter Control, Traffic Control. World leader in the field of C-W Doppler navigation, Ryan Electronics is also making significant progress in solving problems essential to the success of future missions into Space.

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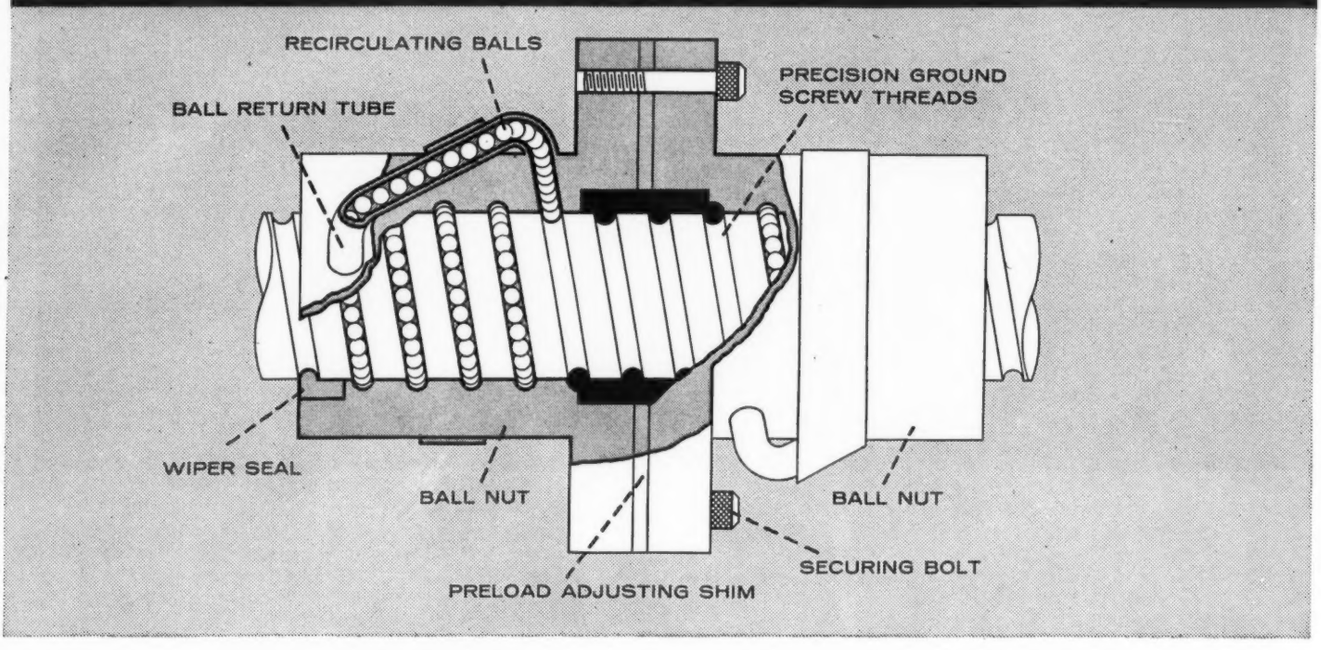
Ryan offers challenging opportunities to engineers

Pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce pre-loaded ball screws.* These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Bristol Siddeley pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. The ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Bristol Siddeley pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

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BRISTOL SIDDELEY ENGINES LIMITED

INTERAVIA AIR LETTER reports...*

New companies, participations, agencies

Aero Space International is a new company set up in Paris to assist U.S. companies engaged in aeronautics and space research and to organize the cooperation of top European scientists under contractual agreement. The company will establish and develop contracts between members of State or private institutions and companies or individuals, will act as a centre of information between the USA and Europe, and will undertake highly specialized studies on specific subjects. It is represented in the United States by Marc Wood International Inc., New York.

●

Compagnie Belge d'Electronique et d'Automation (COBELDA) has been established at Brussels-Gosselies by Hughes Aircraft and the Belgian company SABCA. The new company will handle the maintenance and manufacture of advanced electronic products.

●

Marelli Lenkurt S.p.A. is the name of a new company formed in Milan, with a 51 percent holding by General Telephone and Electric International and 49 percent by Magneti Marelli. The company will manufacture all types of radio transmission, multiplex and carrier equipment.

●

Texas Instruments Inc. is establishing a new subsidiary company, to be known as Texas Instruments France, to manufacture semiconductor devices and components for the European Common Market. The company is studying various sites near Nice and intends to purchase land and construct a modern plant. Meanwhile, initial manufacturing will be carried on in leased quarters in Nice. The new subsidiary will manufacture a full line of silicon and germanium transistors, silicon diodes and rectifiers.

●

Pye Ltd., one of the United Kingdom's leading electronics groups, has purchased a factory at Inverigo, near Milan, and plans to transfer the bulk of its export production to Italy. Although the immediate concern is with domestic equipment, the Pye Chairman has said that his company plans to manufacture in Italy all the items currently sold under the Pye trade mark; these will include communications equipment and specialist radio and telephone equipment. Main reason for the move to Italy is to establish a foothold in the European Common Market area.

●

United Aircraft Corporation has acquired a 20 percent interest in two French companies, Precilec, an electronic manufacturer in Paris, and Somalec, an affiliated engineering company. Precilec, already holding Norden Division licence production rights, now gets exclusive rights for the European Common Market. United Aircraft already has interests in the French SNECMA company, Weser Flugzeugbau in West Germany, and Italian electronics manufacturer Microtecnica S.p.A.

General Precision Equipment Corporation has appointed Mitsubishi Shoji Kaisha Limited as its distributor in Japan for products of G.P. subsidiaries. Mitsubishi will handle the sale of airborne navigation equipment, gyroscopes, microwave components, radar test equipment, electronic computers and similar equipment.

●

Aero Design & Engineering Company has changed its name to *Aero Commander Inc.* The company continues as a wholly owned subsidiary of Rockwell-Standard Corporation, of Coraopolis, Pa.

New contracts for industry

The National Aeronautics and Space Administration is negotiating a $23 million contract with Grumman Aircraft Engineering Corporation for the design, development and construction of a 3,200-lb Orbiting Astronomical Observatory. Grumman's proposal, one of eleven submitted to NASA last July, calls for an eight-sided satellite measuring 9.5 ft in height and 6.5 ft in diameter. The first will be launched late in 1963 into a 500-mile circular orbit aboard an *Atlas-Agena B* rocket vehicle. Grumman will build two OAO space platforms to gather cosmic information in the X-ray, ultra-violet and infra-red portions of the spectrum which is obscured by the earth's atmosphere.

●

McDonnell Aircraft Corporation has received new Navy and Air Force contracts totalling $134,655,236 in value. The Navy's share is a $108,956,520 follow-on contract for additional F4H *Phantom II* fighters for delivery through 1962. This brings the total amount committed for the F4H up to $368,896,623. The Air Force's order includes $24,157,484 for *Quail* missiles and $1,541,232 for F-101 *Voodoo* spares.

●

General Electric Company's Large Jet Engine Department has received a $58,335,000 Air Force contract for continued production of the J79-8 engines for the McDonnell F4H *Phantom II* and the North American A3J *Vigilante*. Deliveries will be made in 1961 and 1962. This follow a $21 million contract for J79 engines for the same aircraft handed out in mid-August.

●

Douglas Aircraft has booked a $71.5 million U.S. Navy contract for continued production of the A4D-2N *Skyhawk* light attack aircraft at El Segundo, California. This is the fourth production award for the *Skyhawk* and brings the total value of contracts for this aircraft to approximately $232 million.

●

Northrop Corporation has received a U.S. Air Force letter contract for the production of a further 144 T-38A *Talon* supersonic jet trainers, bringing the total now on order to 213. Production rate at Northrop's Norair Division will be increased from ten to twelve aircraft per month to meet the new commitment.

Sikorsky Aircraft Division of United Aircraft Corporation has received contracts totalling over $23 million for S-58 helicopters. A Marine Corps order for approximately $19 million covers HUS-1 troop and cargo helicopters for delivery to helicopter transport squadrons during 1962. Finally, a $4,688,319 Navy contract covers HSS-1N helicopters for anti-submarine duties for delivery during 1961.

●

Kaman Aircraft Corporation has received a $21 million contract from the U.S. Navy for production of HU2K *Seasprite* utility helicopters (General Electric T58 engine). Deliveries will begin in 1962. Fitted with advanced navigational and electronic equipment, the Kaman helicopters will be used for anti-submarine tasks and will operate from a wide range of Navy vessels.

●

Britain's Ministry of Aviation has now placed a contract with British Aircraft Corporation for a pre-production batch of TSR.2 tactical strike and reconnaissance aircraft to enter squadron service with the RAF in 1965. The initial order is believed to cover less than a dozen aircraft, and the first is expected to fly in about the spring of 1963. Constructional work has already started, and design and production will be shared equally between Vickers-Armstrongs and English Electric. The U.S. Defense Department is still studying a possible requirement for the TSR.2 weapons system, and Secretary of the Air Force Dudley Sharp has asked to be kept informed of progress made.

●

Western Electric Company and Bell Telephone Laboratories (both subsidiaries of American Telephone and Telegraph Corporation) have received a $199,125,000 Army contract for research and development work on the *Nike-Zeus* anti-missile missile. The contract covers installation and testing at Whippany and at White Sands Proving Grounds in New Mexico.

●

The Raytheon Company has received contracts totalling $29,597,725 for continued production and engineering service on the *Hawk* missile system.

Other industry activities

Boeing Airplane Company's IM-99B *Bomarc* surface-to-air missile has been officially accepted by the U.S. Air Force for quantity production, and the Air Force can now release $294 million appropriated by Congress for this weapon. Approximately $50 million of the total will be used for continued research and development. Five squadrons of an estimated 40 missiles each will be deployed in the United States and Canada, a sharp reduction in the original number of squadrons planned.

●

The U.S. Army reports development of a 68-lb rocket-powered ejection seat for emergency escape from VTOL aircraft while operating at low altitudes. The seat, equipped with an automatic quick-opening parachute, weighs only half as much as similar units now in use. Contractor is North American Aviation, Inc., of Columbus, Ohio.

●

Ateliers d'Aviation Louis Breguet is carrying out a design study on a 22,000-lb light transport within the 941/942 family of blown-wing aircraft. The design is designated Breguet 945 and has four propellers driven by two Turboméca *Turmo IIIBs*. Payload will be in the order of 3,300 lb, range 950 miles and speed 250 m.p.h. The 945 will have capability for short take-off and landing from high-altitude or tropical runways with

* Interavia Air Letter is a daily international news digest published in English, French ("Courrier Aérien") and German ("Luft-Post"). All rights reserved.

a length of under 985 ft. Radius of turn under 200 ft at a speed of 60 knots.

●

The French Government is sponsoring SNECMA development of the Pratt & Whitney JTF10 small axial-flow dual-compressor turbofan engine. Thrust is to be increased, and weight reduced to meet NATO S/VTOL applications.

Airlines and airports

The IATA Joint Traffic Conferences meeting in Cannes terminated in mid-October with no major decisions being taken to affect the present position. A decision to hold the Joint Traffic Conferences every second year in future is read as an indication of the stability achieved in the fares situation. Agreement was, however, reached on reduced tariffs to be applied to Pacific routes and the introduction of economy class between North and South America. A special conference on freight rates will be held in Paris beginning on January 24th, 1961.

●

Aeroflot, the Soviet Union's national carrier, reports steady and impressive increases in traffic over recent years. In 1959 revenue tonne-km increased by 29 percent, passenger volume by 48.5 percent, freight by 28.9 percent and mail by 11.3 percent, compared with the previous year. About half of the total traffic is carried in twin-engine aircraft on domestic services. Operating costs have been reduced by 15 to 20 percent, and cuts in passenger, freight and mail rates have brought new traffic.

Aeroflot now operates jet aircraft on 65 national and 20 international routes. In 1959 jet aircraft carried 30 percent of the total traffic, compared with 17 percent in 1958, while in 1960 the figure is up to 60 percent.

●

The Transports Aériens Intercontinentaux Board has appointed General Georges Fayet as President, in succession to the late Paul Bernard.

●

The Iraqi Ministry of Communications has invited tenders for the construction of an international airport on a site at Qasr-el-Meleh, about 20 km west of Baghdad. The work involved will include a 9,800-ft by 150-ft runway, a main taxiway, exit taxiways and aprons, secondary access roads, complete airfield lighting installation, water and fire mains and a complete sewage system.

●

Berlin-Schönefeld Airport's new 11,810-ft jet runway was completed at the end of September, and work on the taxiways and parking areas is scheduled for completion in November. Construction work is also due to begin in 1961 on a new passenger terminal in the northern area of the airfield, three miles nearer the city than the present southern building. The airport is also to have a fast motor road and electric railway connections with the city.

First flights, certification tests

The twin-turbine Vertol 107 helicopter has been undergoing FAA certification tests, and production is under way on the first of ten Model IIs ordered by New York Airways, with delivery scheduled for next April onwards. The last of the ten will be handed over in July 1961. Meanwhile, the fuselage of a permanent metal mockup of the Model II is virtually complete.

●

The first Convair 880-M began flight testing at the beginning of October. The 880-M version is designed especially for short and medium-range routes with shorter take-off and landing distances. It has the following optional features which can be fitted to meet specific airline requirements: power-boosted rudder, General Electric CJ-805-3B engines of 11,650 lb thrust, four leading edge slats between the engine pods and outboard of the engines. It is also designed to take additional fuel in three of the five bays in the outer section of the wing.

●

The Lockheed Super 26 executive transport, a modification of the twin-engine B-26, has been granted its FAA certificate. Modification work, which includes fitting of a pressure cabin, was carried out by Lockheed Aircraft Services at its Ontario, California, plant, under contract to Mesa Machine Company, of Pittsburgh, Pennsylvania.

●

A prototype of the Hindustan Aircraft HF-24 supersonic fighter is to begin tests in February 1961, say Indian sources. The aircraft will not at this time be fitted with the Bristol Siddeley *Orpheus BOr.12* engines planned for the production version, but will be powered by an earlier version of the *Orpheus*. The Indian Government is advocating an acceleration in the HF-24 programme and wishes production to begin in 1961.

●

The Klemm Kl 107D four-seat sports and touring aircraft (one 180 h.p. Lycoming engine) built by Bölkow-Apparatebau GmbH, made its first flight on October 10th, 1960. Delivery of the production model will begin in early 1961.

Research rockets, experimental aircraft, rocket motors

Project Vela is the name given to a U.S. Air Force programme to develop methods of detecting and identifying nuclear explosions. Under this programme, Texas Instruments Inc. has been awarded a contract to develop multiple arrays of seismic sensors and data processing equipment.

●

A new research space vehicle that can be launched from Navy carrier-based fighters is being developed at the U.S. Naval Ordnance Test Station, China Lake, California. The four-stage solid-propellant rocket is called *Caleb,* is designed for projecting probes horizontally, but can also be fired vertically for high-altitude studies. *Caleb* also has potential capabilities for orbiting small payloads. It can be used with various booster configurations with one, two, three or four stages of propulsion. Finally, it can be carried on standard bomb racks on such aircraft as the F4H *Phantom II* or F4D *Skyray*. Length 16.5 ft, diameter 2 ft, weight at launch 3,000 lb.

●

Aerolab ARGO E-5 is the designation of a new sounding rocket produced by Aerolab Development Company, of Pasadena, California, a subsidiary of Ryan Aeronautical Company. The five-stage research vehicle is designed to reach altitudes of more than 1,000 miles.

●

The eighth launch in the U.S. Air Force's Phoenix programme took place at Point Arguello, California, on October 12th, when a two-stage solid-propellant missile reached an altitude of 200 miles before falling into the Pacific Ocean 100 miles downrange. The *Phoenix* programme is being conducted for the U.S. Air Force by the University of Maryland and is designed to measure electron density and various types of radiation at high altitude.

●

The National Aeronautics and Space Administration is conducting a series of tests designed to investigate the nature of the Van Allen belts, using NERV (Nuclear Emulsion Recovery Vehicle) payloads boosted by four-stage solid-propellant *Argo D-8* sounding rockets. NERV was designed and developed by General Electric Company's Missile and Space Vehicle Department, of Philadelphia, Pa. The launch vehicle is manufactured by Aerolab Development Corporation, of Pasadena, California; the first stage motor is produced by Thiokol Chemical Corporation, the second and third by Grand Central Rocket Company, and the fourth by Allegany Ballistics Laboratories, a division of Hercules Powder Company.

●

The North American X-15 with the Thiokol-Reaction Motors XLR-99-RM-1 rocket motor may have made its first flight by the time these lines appear in print. The 60,000-lb thrust engine is still in the research and development phase, and the higher-powered X-15 will be tested gradually over a period of months through the entire performance range to verify and qualify the motor. The first X-15, fitted with two XLR-11 rocket motors, is being used to train four back-up pilots; the second carries the new motor, and a third is being completed at North American's Inglewood plant; it will also have the XLR-99 engine.

●

Piasecki Aircraft has been granted a U.S. patent covering the design of the Piasecki S/VTOL "Ring-Wing" aircraft and its so-called integrated propulsion and lift systems (an integrated propulsion, lifting and propeller slipstream deflecting unit). The design incorporates propellers mounted within two circular wings; each ring-wing is fitted with an arrangement of flaps and vanes that can be lowered to deflect the propeller slipstream downward, if short or vertical take-offs and landings are required.

Piasecki has built a powered wind-tunnel model of the aircraft under contract to the Navy Bureau of Aeronautics. This model has undergone considerable testing at the Navy's David Taylor Model Basin wind tunnel in Washington. Data obtained from the ring-wing tests have made important contributions to the development of the Piasecki aerial jeep, the *Sky-Car I,* which was flown in 1958 under an Army contract, as well as the *Sky-Car II* now being built by the company.

●

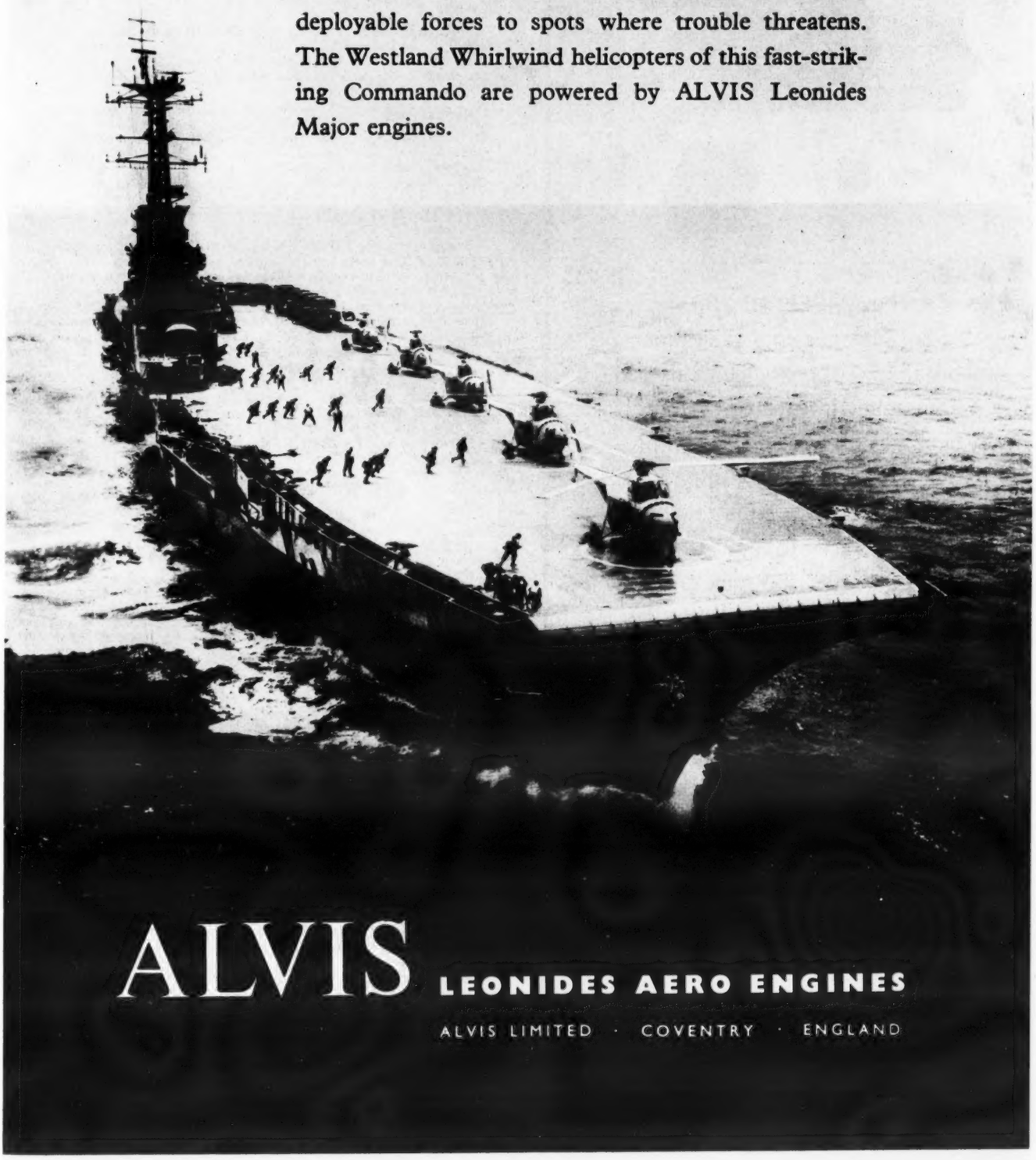
Bell Aerosystems Company has developed, under contract to NASA, a new rocket engine using fluorine and hydrogen as propellants. The feasibility of employing fluorine as an oxidizer has been demonstrated in more than 600 static tests conducted over the past four years. In 300 of the firings, hydrazine and hydrazine blends were used as fuel, while in the remainder liquid hydrogen and ammonia filled this role. During the course of its work Bell Aerosystems has also developed a high-speed fluorine-hydrogen turbo-pump with large output capacity and high discharge pressures.

●

The U.S. Government plans to make rockets and launching facilities available to private industry interested in developing a global communications network utilizing passive and active satellites. At least two firms are interested in satellites for long-distance communications. American Telephone and Telegraph has disclosed plans for a $170 million programme calling for 50 satellites (probably both active and passive) to be placed in random orbits about 3,000 miles in space; AT&T says it plans to cooperate and share costs with other countries interested in the programme. International Telephone and Telegraph Corporation is also interested in a commercial application. Both firms have served as major contractors on NASA and Air Force communication satellite programmes. *Continued on page 1326*

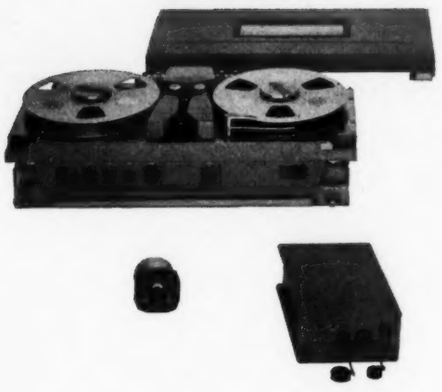
Emergencies demand reliability

42 Commando, Royal Marines, is part of the complement of H.M.S. *Bulwark*—the Royal Navy's first Commando carrier. It is *Bulwark*'s task to rush rapidly deployable forces to spots where trouble threatens. The Westland Whirlwind helicopters of this fast-striking Commando are powered by ALVIS Leonides Major engines.



ALVIS LEONIDES AERO ENGINES

ALVIS LIMITED · COVENTRY · ENGLAND



The AMPEX AR-200

is an analogue magnetic tape recorder for airborne or mobile use. A completely integrated system, it occupies just 1.6 cubic feet of space and weighs only 95 pounds. The AR-200 performs reliably from −54° C. to +71° C., at altitudes to 100,000 feet, and will withstand 15g shocks and 10g vibration. Electronics are all solid state, and the recorder operates on 28 volts DC. Converters are available for use with other power sources. Standard speeds are 1⅞, 3¾, 7½, 15, 30 and 60 inches per second. The AR-200 can be used for direct, FM-carrier, PDM or digital recording. Models are available for up to 14 analogue tracks or 16 digital tracks. I. R. I. G. compatible at no extra cost. For specifications write to Ampex Great Britain Limited, Arkwright Road, Reading, Berks., England. AMPEX

INTERAVIA AIR LETTER Reports...

(Continued from page 1324)

Projects — New Aircraft; Engines

Hiller, one of the few U.S. helicopter manufacturers which have not yet made large-scale use of turbine powerplants, has been making a series of studies with a view to fitting shaft turbines to existing helicopter airframes adapted for the purpose. Among the possibilities being investigated is the installation of a Boeing T60 shaft turbine in a U.S. Army H-23 helicopter. Further shaft turbines under consideration are the Allison T63, the Continental 217 and the Canadian Pratt & Whitney PT-6 (T74).

●

A prototype of the FBA-2A light bush transport built by Found Brothers Aviation Ltd. of Malton, Ontario, is undergoing flight tests. It has a four- to five-passenger layout, but can also be used to transport freight. Powerplant: one 250 h.p. Lycoming O-540-A1D.

●

Vickers is reported to have worked out plans for the development of a "stretched" Super VC.10. The fuselage length would be increased by 10 ft, and the aircraft would be able to carry up to 222 passengers. It would be powered by four developed *Conway* by-pass engines. Range with full payload would be over 4,000 nautical miles. Two unspecified European airlines are said to be interested in this version of the Super VC.10.

●

General Electric's Rocket Engine Section has been awarded contracts totalling more than $ 1 million for research and development work on the plug nozzle rocket motor concept, by which varying thrust requirements can be met by changing the number of chambers around a central thrust cone. General Electric will investigate improved methods of controlling the force and direction of solid-propellant rocket thrust and evaluate various configurations of the basic plug nozzle idea for liquid and solid rockets.

●

North American's first production T-39 Sabreliner has made a 1,820 mile non-stop test flight. During the flight, the T-39 cruised at 540 m.p.h., thus considerably bettering the design cruise speed of 500 m.p.h. The flight was made at an average altitude of 45,000 ft. The U.S. Air Force has ordered an additional 52 *Sabreliners*, thus bringing current production orders to 94 aircraft.

●

Delivery of the new 1961 Piper Comanche will start this month. The 1961 *Comanche* is offered in four models—Standard, Custom, Super Custom and AutoFlite with either a Lycoming O-360-A (180 h.p.) or a Lycoming O-540-A1A5 (250 h.p.). A new feature of the 1961 *Comanche* will be the Piper *AltiMatic* autopilot (as optional equipment); in addition, the aircraft is available with 90 U.S. gallons fuel capacity, an increase of 30 gallons over previous models. This gives an endurance of over six hours at maximum cruise speed of 181 m.p.h. Gross weight of the 250 h.p. version is 2,900 lb, of the 180 h.p. version 2,550 lb.

Equipment and Accessories

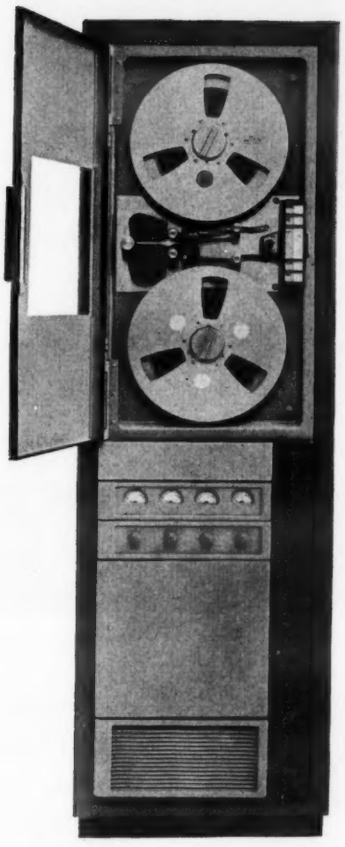
Tests on automatic blind landing systems will be carried out at Hanover-Langenhagen Airport during the coming winter, with the aim of working out proposals for a standardized international system. The tests are being supervised by the Blind Landing Working Group (Arbeitskreis Blindlandung). Two systems have been selected for thorough investigation and practical testing: the British *Autoland* system (Smiths) and the American Bell system. A *Noratlas* and several helicopters are being used for the tests.

●

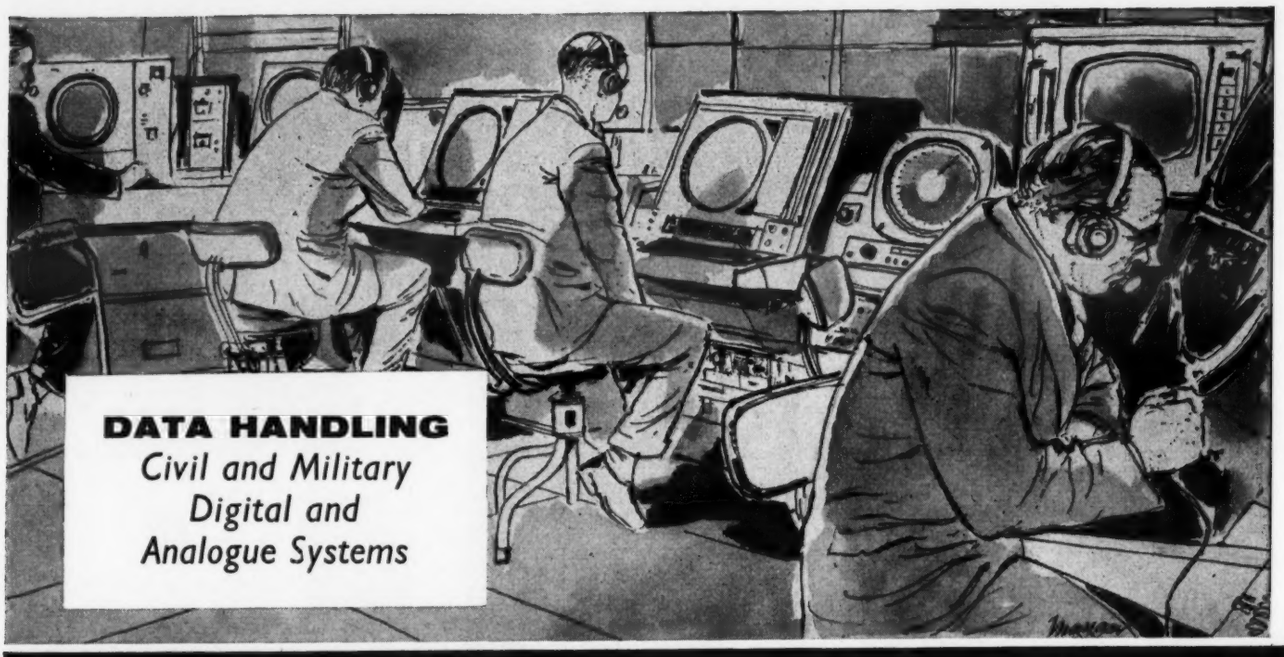
Baird-Atomic Inc. has delivered the first of a series of infra-red surveillance satellite payloads to the Missiles and Space Division of Lockheed Aircraft Corporation, which is prime contractor for the Air Force *Midas* programme. The Baird-Atomic payloads incorporate a number of advances in optics, infra-red detectors, transistorized electronics and mechanical engineering.

●

Ling-Temco Electronics Inc. is welding and machining a new columbium (niobium) alloy, F-48, at its Temco missiles plant, in connection with the Air Force Refractory Metals Structural Development Program, which involves fabrication and testing of a structural component under simulated re-entry environments. McDonnell Aircraft Corporation holds the prime contract for the programme, and Hughes Tool Co. and General Electric Co. are also members of the team.



The AMPEX FR-100B is a high performance instrumentation magnetic tape recorder suitable for a wide variety of industrial and scientific applications. In manufacturing it is used extensively in both machine tool and process programming. In research it will record such diverse things as the thrust measurements of a jet engine, cosmic ray counts from a satellite, or vibration data developed in testing a new car body. This information can be recorded by direct techniques, on an FM carrier, by pulse duration modulation, or through NRZ digital techniques. It is capable of recording up to 14 analogue or 16 digital tracks, operates at any of 6 standard speeds from 1⅞ to 60 inches per second... can be modified for other speed combinations. And, depending on the system used, it will record from a direct current signal up to 100 kilocycles, ±3 db. The FR-100B will also reproduce tapes it has recorded, or those made on similar Ampex machines. I. R. I. G. compatible at no extra cost. For complete information on this remarkable recorder write to Ampex Great Britain Limited, Arkwright Road, Reading, Berks., England. AMPEX



DATA HANDLING
Civil and Military
Digital and
Analogue Systems

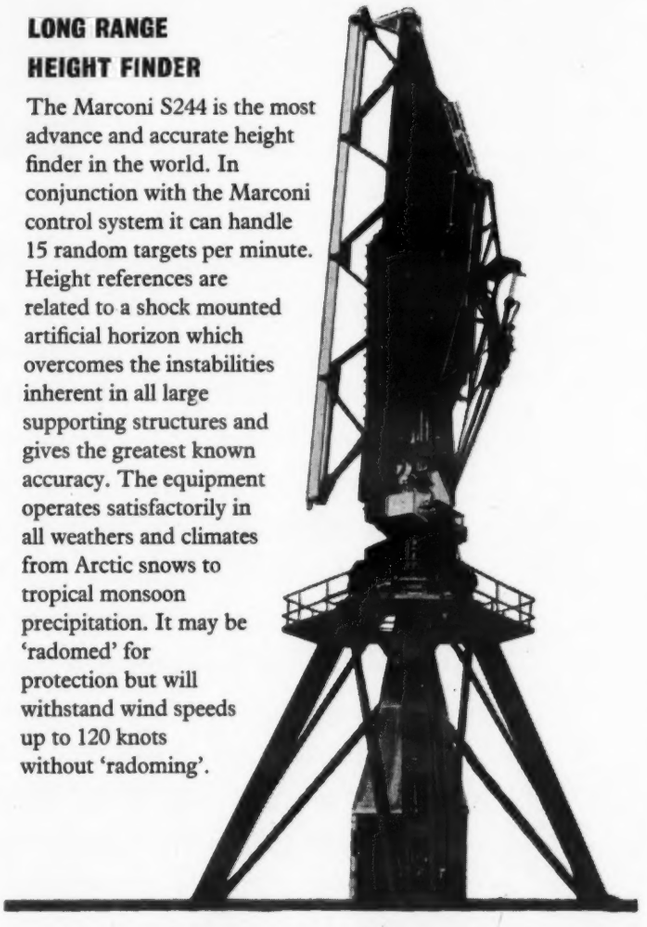
MARCONI'S cover the

STORM WARNING RADAR

The Marconi SNW 51 is designed to present accurate pictures of storms and rain producing clouds over ranges up to 200 n. miles. It meets the needs of Meteorological Departments and Civil Aviation Authorities, particularly where data gathering from distant recording posts is uneconomic or hampered by inaccessibility. It is used by the British Ministry of Aviation and in Australia, Southern Rhodesia, British East Africa and China. Its main features include: (i) Full off centring on displays; (ii) controlled camera recording facility; (iii) remotely controlled tiltable aerial; (iv) Iso-echo presentation.

LONG RANGE HEIGHT FINDER

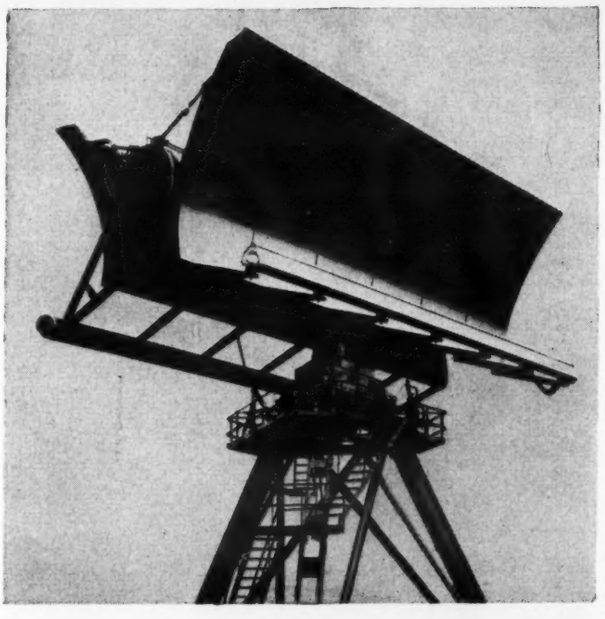
The Marconi S244 is the most advance and accurate height finder in the world. In conjunction with the Marconi control system it can handle 15 random targets per minute. Height references are related to a shock mounted artificial horizon which overcomes the instabilities inherent in all large supporting structures and gives the greatest known accuracy. The equipment operates satisfactorily in all weathers and climates from Arctic snows to tropical monsoon precipitation. It may be 'radomed' for protection but will withstand wind speeds up to 120 knots without 'radoming'.



AIR TRAFFIC CONTROL SYSTEMS

The Marconi S264A 50 cm. radar is the most advanced air traffic control radar in the world. It will operate anywhere, including mountainous country, in all weather conditions. It is designed for the control of jet aircraft from take-off to 150 miles plus, combining the three roles of Airfield Control, Terminal Area Control and Long Range Airways Surveillance. Several versions are now available to suit varied circumstances and continuous research is being devoted to ensure continued progress and development of Marconi 50 cm. radars.

whole field of ground radar



LONG RANGE SURVEILLANCE RADAR

This versatile radar can be adapted to a diversity of applications. The Moving Target Indicator eliminates the echoes from stationary objects. Distortion of the reflector profile is prevented by the main member being a 6′ 8″ diameter tube, thus giving increased accuracy over a longer life. A unique mechanical design feature ensures that the turning gear is unaffected by slight subsidence of the site. Like the S244 the equipment is 'all weather' and 'all climate' and will withstand wind speeds up to 120 knots without 'radoming'.

Marconi's offer a complete consultancy and engineering service in the installation of radar systems. All Marconi radars and data handling equipment have been designed for integration into the most advanced air traffic control and defence systems at present in operation or contemplated in the foreseeable future. Marconi radar is in constant use in 36 countries.

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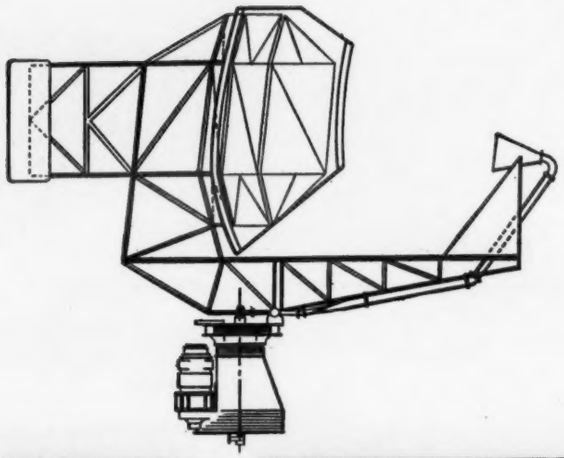

PHILIPS

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SURVEILLANCE RADAR ELEMENT

To match the increasing use of jet aircraft and the growing density of air traffic, a higher standard of safety precautions is required at airports. PHILIPS long-range Air Route Surveillance radar and Approach Control radar have been specially developed to meet this demand for safe and flexible air traffic control under any circumstances. The utmost reliability is ensured by using high quality components and transistorized circuits. Logical 'unit' construction and many other features permit the formation of radar systems meeting all the special requirements of any airfield. Surveillance Radar Element : another dependable system in the PHILIPS radar programme.

PHILIPS' long-range Air-Route Surveillance radar at Schiphol Airport, Amsterdam

PHILIPS N. V. PHILIPS' TELECOMMUNICATIE INDUSTRIE, HILVERSUM, THE NETHERLANDS

At high speeds, at high altitudes, U.S. Air Force pilots will learn to fly today's high-performance aircraft in twin-engined T-38 TALON supersonic trainers. The U.S. Air Force has already ordered 213 Northrop TALONS and more are programmed.

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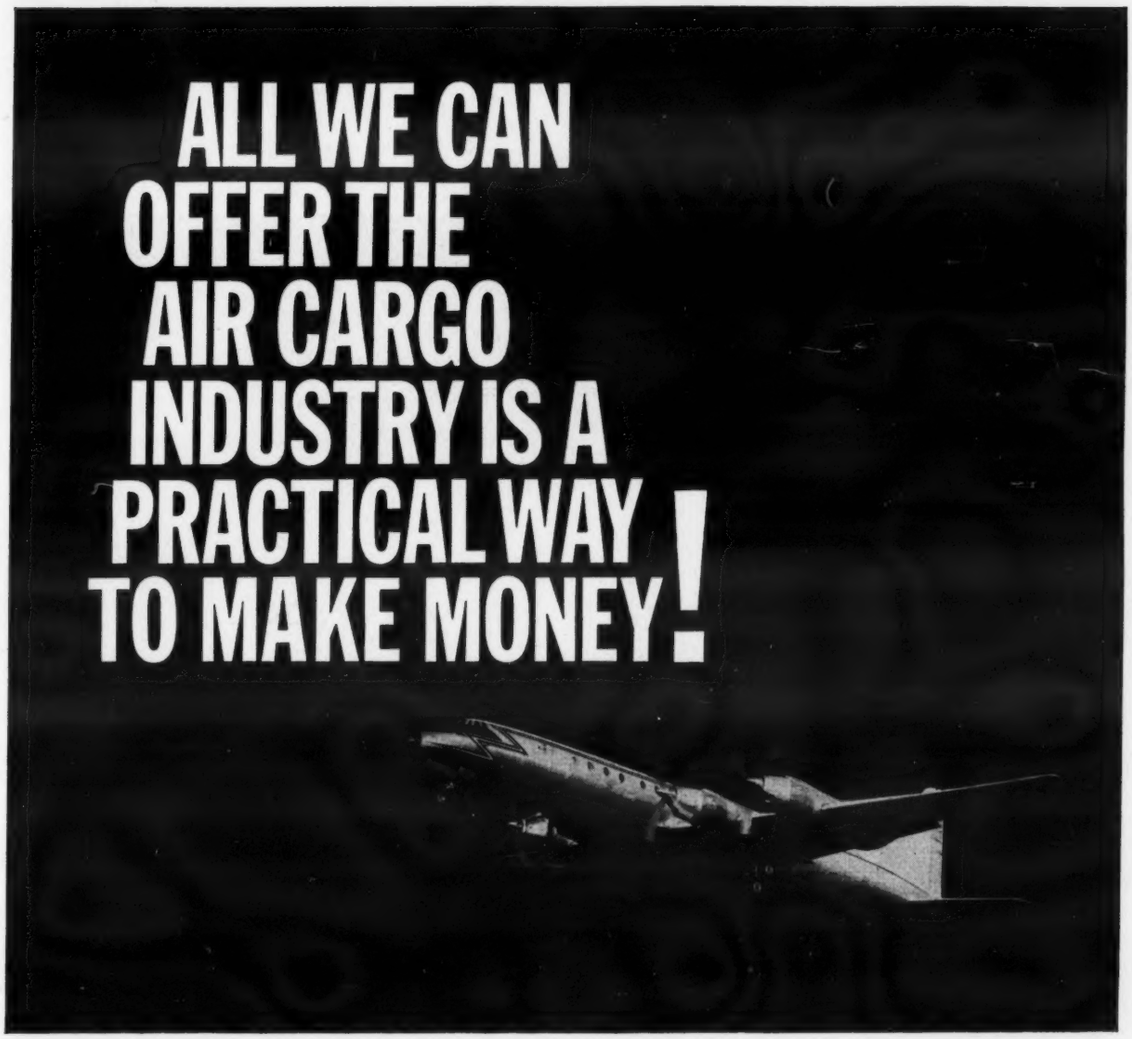

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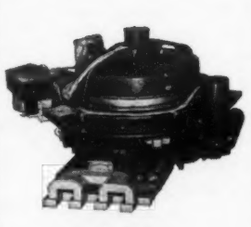

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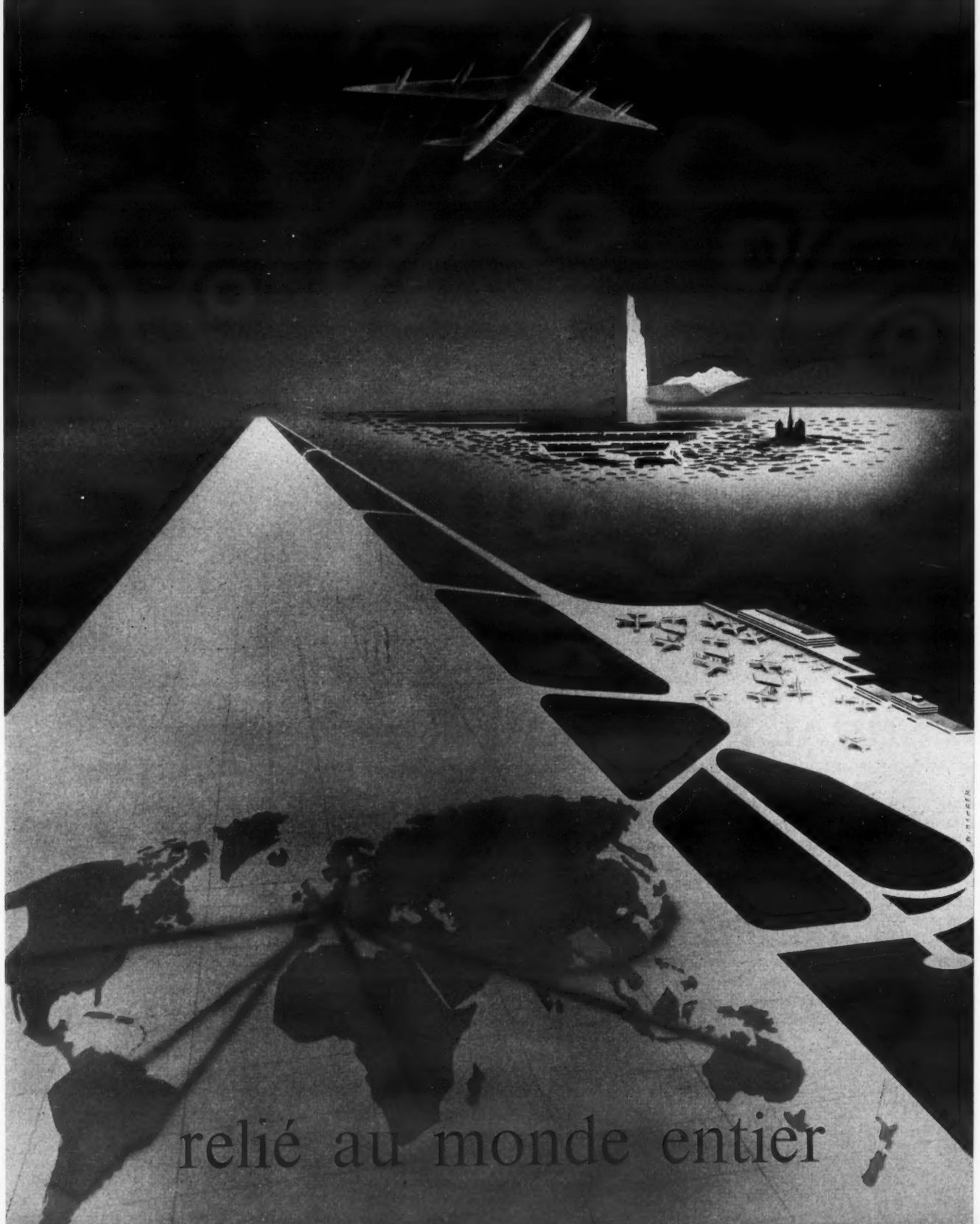

relié au monde entier

Douglas is construction foreman on the longest road in the universe

New device allows pilot to drive down a visual highway to his destination, even through densest fog

Now being perfected under U. S. Government auspices is a remarkable control panel design for aircraft, which can also be adapted to other vehicles.

The unit, fed by a computer which can make a quarter of a billion calculations per second, projects a symbolic highway on a transparent TV screen in front of the pilot. This "pathway in the sky" guides him unerringly to his exact destination, keeping him on course and at correct speeds *even when visibility is zero.*

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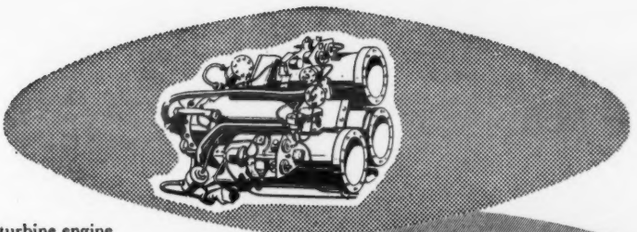
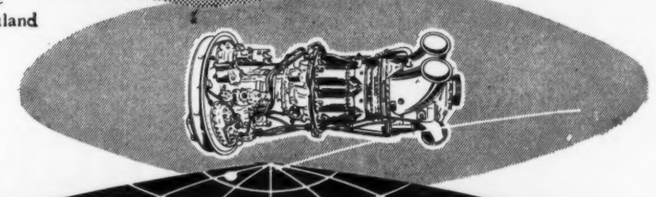


TRIPLE SCORPION an aircraft rocket engine which provides a source of extra power at all altitudes. Designed for sustained firing and long operational life.

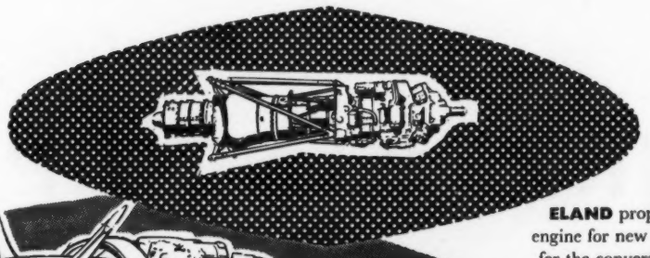
GAZELLE free turbine engine (1650 s.h.p.) powers the Westland Wessex and the Bristol 192. Now chosen to power the twin-engined Wiltshire.

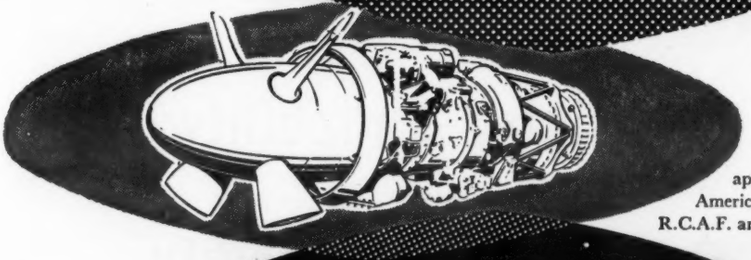


NAPIER AERO ENGINES

for the world

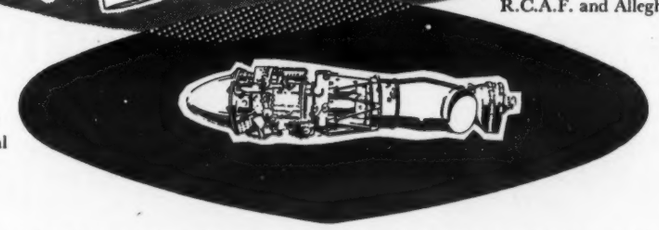
ELAND engines designed for the Fairey Rotodyne are basically the standard Eland with an auxiliary compressor mounted at the rear.





ELAND propeller-turbine engine for new airliners and for the conversion of piston engined airliners. The Eland which powers the Canadair 540 and Convair 540, is rated at 3,500 e.h.p. and is approved by British A.R.B. and American F.A.A. In service with the R.C.A.F. and Allegheny Airlines U.S.A.

ELAND engines for the Westminster are installed horizontally on top of the fuselage with a mechanical drive to the rotor shaft.



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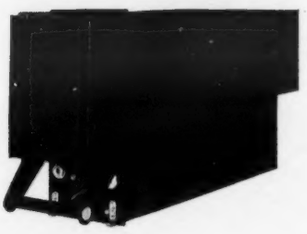

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ABILITY

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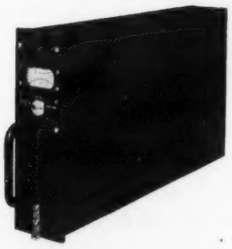
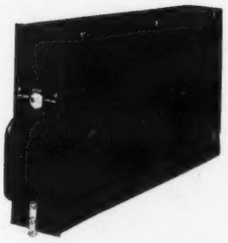
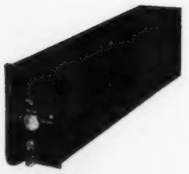


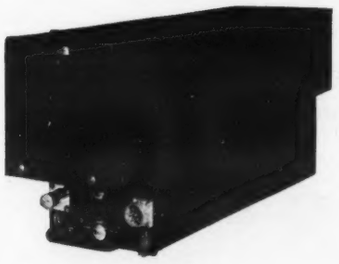
AD 260
V.H.F. Navigation system.
Navigation unit type 6402
(short ½ ATR. 9 lbs.).



AD 260
V.H.F. Navigation system.
Glide Slope Receiver type
6404 (short ½ ATR. 6 lbs.).



AD 260
V.H F. Navigation system.
Marker Receiver type 6403
(dwarf short ½ ATR. 3 lbs.).



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ADF Receiver type 6407
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The G 91 T landing on grass

Fiat G 91 T — Bristol Siddeley Orpheus 80302 engine

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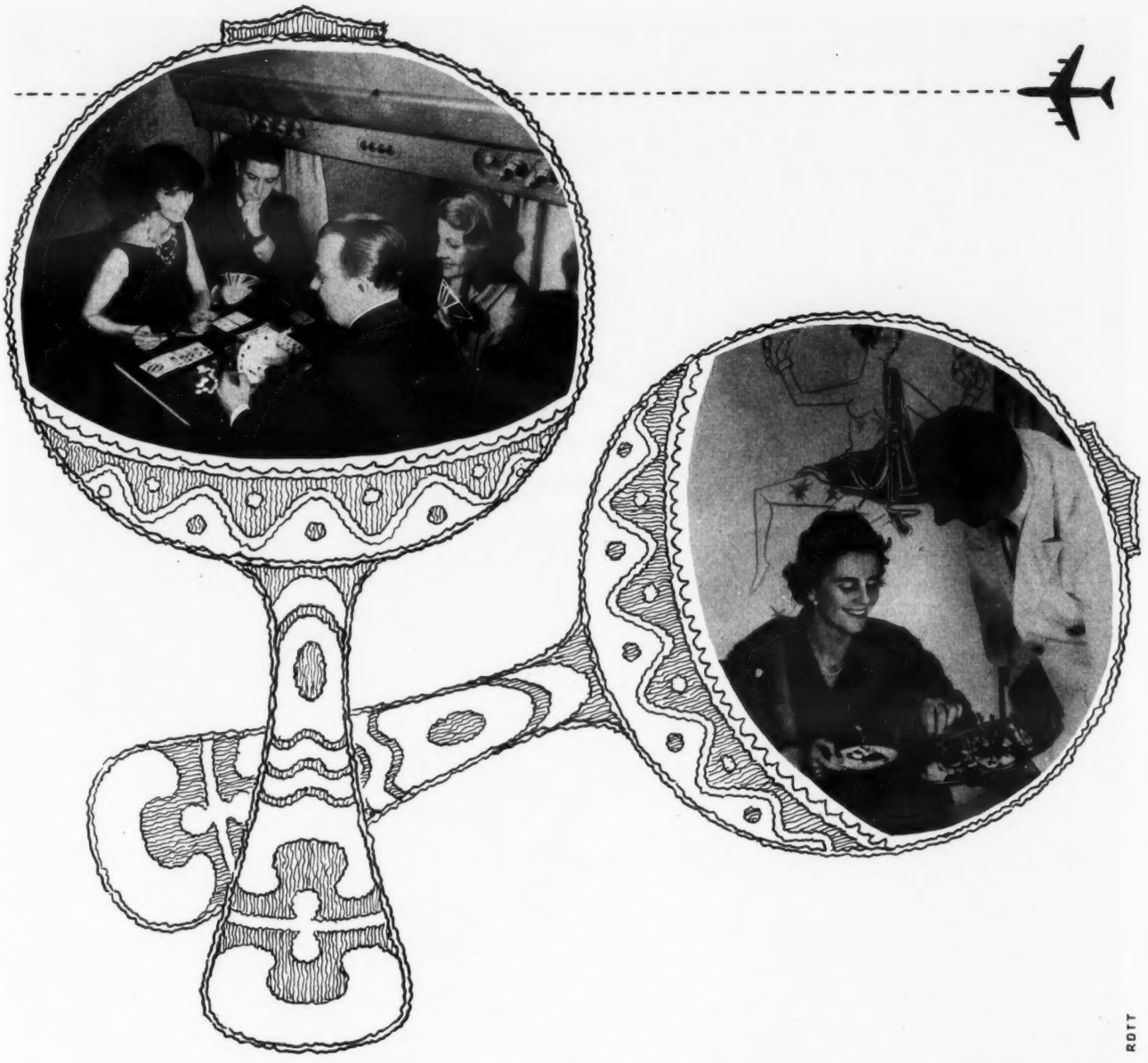

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BOC

The Mind of Mr. Reader

Kneeling Aircraft

Sir,

The article "Converting Outdated Passenger Aircraft" in the August 1960 issue mentions Freddie Laker's scheme for converting DC-4's for use in the Air Charter Co., and that these converts may be called "Flying Camels."

Camels kneel to be unloaded and loaded. Why can't aircraft do the same? The Messier Co. apparently agrees as per the article on the Transall C.160 in the September 1960 issue.

The DC-4, "Connie," etc. stand high in order to give clearance for their propellers, but when the aircraft and propellers are stationary, it should be possible to lower the aircraft some 4 feet by setting the propeller blades obliquely to the ground, and contracting the landing gear by means of some modification to permit a "semi-retracted" position.

This would bring the aircraft floor to about truck-bed height and considerably ease the loading/unloading problem.

Also in the September 1960 issue, casual mention is made on page 1072 of a projected pure freight VC.10 (*with swing nose?*). This makes me wonder if Freddie Laker couldn't achieve his ends by giving the DC-4 a swing nose (as opposed to the Canadair CL-44's swing tail) and perhaps "kneeling" landing gear.

Tel Aviv — **Roy Dinar**

The most surprising results, of course, can be obtained through good training. "Down, Connie! Down!" *Ed.*

Conference fatigue

Sir,

Exhausted and vacation-ripe after a summer in which aeronautical, astronautical or other "nautical" congresses have sent me chasing from one end of Europe to the other, I am disappointed to see that you apparently do not consider my suggestion worth publishing. I am, of course, referring to the suggestion which I have already made to several of your editorial staff whom I have met on these occasions.

Now I hope that by writing this letter, I can get my ideas into print in your journal. This is my suggestion once again: if all the different national and international scientific societies and associations really cannot desist from organizing mammoth lecture sessions every year—sessions whose names are often confusingly similar—why could the locations and dates of congresses not be fixed in such a way that one could participate in them without wasting too much time or incurring too heavy costs. I have noticed that at the many cocktail parties, receptions, steamer trips and banquets—and even sometimes at the lectures—one constantly runs into the same people.

One of the newer branches of learning, known as Operations Research, deals among other things with so-called transport problems. A typical task here is, given a known point of departure and a known destination, so to organize the movement of persons or goods that transport costs or transport times are reduced to a minimum. It seems to me that the choice of congress locations and dates has been regarded as a similar transport problem . . . but with opposite signs, namely in such a way that the result is the longest possible journey for the participants. Or is the whole thing perhaps a manœuvre to increase passenger volume for the airlines?

Carrying my idea a step further, would it not be possible to arrange that all those congresses which in any case change their locations from year to year should be held in the same city in any given year and that they should directly follow one another in time? This would not only save an enormous amount of administrative and preparatory work—incidentally lecture halls are already in short supply owing to this inflation of congresses—but would also provide a welcome opportunity for tightening up the lecture programmes. At present, for example, not only are the same topics dealt with at several different conferences, but it can even happen that the same people read the same papers.

Then, a notorious congress visitor such as myself would not have to change hotels a dozen times in two months or, as soon as he had learned a few vital expressions in one language, battle with taxi drivers in yet another. Finally, you yourselves would only need to release one of your staff for a few days in order to cover the whole list.

I hope that the latter argument will remove any doubts you may have had as to the validity of my proposal.

As I fear that the hotel trade and the airlines may put me on their black list for my remarks, you will understand that I must ask you to preserve my anonymity, should you decide to publish this letter.

Munich — **L. M.**

We cannot altogether disagree with the arguments of this reader and would suggest—for fairly obvious reasons—that Geneva would be an ideal location for next year's European congresses. *Ed.*

An irritated taxpayer

Sir,

In the course of my professional duties, I make a point of reading your daily *Interavia Air Letter* regularly, and was struck in one of the recent issues by your account of the joint employer/employee conference on civil aviation organized in Geneva by the International Labour Organization. Basically, I occupy a neutral position on this question, since I do not belong to either category. But it did strike me that here again, as so often happens in international conferences, so much effort should have been expended for so little result. If some 100 people are to be gathered together from 18 countries in three continents, surely it would pay to prepare the negotiations sufficiently thoroughly beforehand so that some real progress can be achieved at the actual conference.

The main topics for discussion covered general working conditions for flight crews. But the airlines appear to have declined to tackle the central questions raised. Instead agreement was ultimately reached on only a few secondary points. Had the conference been properly prepared, it should surely have been possible to foresee this outcome.

If I remember correctly, a similar conference with the same programme was held as long ago as 1956, when the result was also virtually nil. I have, of course, no objection to the International Labour Organization's attempting to reconcile the viewpoints of airline employers and their personnel. But I do feel that there is a case for being somewhat less open-handed with the taxpayer's money. Items such as "employment of staff abroad and their repatriation," or "request that ICAO should take working conditions into account in the study of technical and operational problems" could surely be agreed upon without a monster conference in Geneva. After all, the taxpayer's money does not grow on trees.

Bordeaux — **R. Lefébure**

No comment! — Ed.

Polaris submarine list not secret

Sir,

In the last issue of *Interavia* (No. 9, 1960) there is an article by Scott Hershey ("Wall Street Watches the Missile Manufacturers") which surprised me, as I do not understand why he says that "The Navy doesn't say which of its submarines are equipped with *Polaris* missiles," when everyone knows the names and the number of these submarines.

I myself can enumerate them for you very quickly. They are five units of the *George Washington* class (displacement 5,600 tons; length 380 ft; beam 32 ft; one type S5W engine); in detail, they are: the "George Washington" (launched on June 9th, 1959, commissioned on December 30th, 1959, now in fleet service; built at Groton, Conn.); the "Patrick Henry" (launched on September 22nd, 1959, commissioned in March 1960, now in fleet service; built at Groton, Conn.); the "Theodore Roosevelt" (launched on October 3rd, 1959, commissioned in June 1960, now in fleet service); the "Robert E. Lee" (launched on December 18th, 1959, being outfitted at Newport News, Va.); the "Abraham Lincoln" (launched in April 1960, now being outfitted at Portsmouth). The designations of these five submarines are SS(B)N-598, 599, 600, 601 and 602.

Next there are seven of the *Ethan Allen* class (displacement 6,900 tons; length 390 ft; beam 33 ft; one type S5W engine): the SS(B)N-608 "Ethan Allen" (on the stocks at Groton, Conn., due for launching this year); the SS(B)N-609 "Sam Houston" (on the stocks at Newport News, Va.); the SS(B)N-610 "Thomas A. Edison" (on the stocks at Groton, Conn.); the SS(B)N-611 "John Marshall" (on the stocks at Newport News, Va.); and finally, the SS(B)N-616, 617 and 618, all of the same class and all armed with *Polaris* missiles, but simply "authorized" at the moment.

Milan — **Giampaolo Ferone**

Signor Ferone's correction is accepted with thanks. *Ed.*

INTERNATIONAL MEETINGS AND CONFERENCES

Oct. 25th-Nov. 21st: ICAO Airworthiness Committee. Montreal.

Nov. 1st-2nd: Radio Technical Commission for Aeronautics, Fall Meeting. Washington, D.C.

Nov. 2nd-4th: Tenth Aircraft Hydraulics Conference. Detroit, Mich.

Nov. 4th-5th: Institute of Radio Engineers Symposium. Montreal.

Nov. 8th-11th: Society of Die Casting Engineers, First National Die Casting Exposition and Congress. Detroit, Mich.

Nov. 14th-16th: National Convention, National Aeronautics Assn., Indio, Calif.

Nov. 14th-18th: Flight Safety Foundation's 13th Annual International Air Safety Seminar, in cooperation with Aviation Crash Injury Research. Phoenix, Ariz. For FSF members and by invitation.

Nov. 15th-16th: 12th Annual Mid-American Electronics Conference, Institute of Radio Engineers. Kansas City, Mo.

Nov. 15th-17th: Air Force-Navy-Industry Propulsion Systems Lubricants Conference (unclassified). San Antonio, Tex. Cosponsors: ARDC's Wright Air Development Division; Southwest Research Institute.

Nov. 15th-17th: Aviation Distributors and Manufacturers Association, 36th Meeting. Palm Springs, Calif.

Nov. 21st-25th: Second Industrial Photographic and Television Exhibition. Manchester.

Nov. 23rd: Society of Environmental Engineers, "Vibration testing and instrumentation of large stores." London.

Dec. 5th-8th: 15th Annual Meeting and Astronautical Exposition, American Rocket Society. Washington, D.C.

Dec. 5th-11th: World Airline Employees Convention. Las Vegas, Nev.

Dec. 6th-8th: National Aviation Trades Association, Annual Meeting. Oklahoma City.

Dec. 13th-15th: Eastern Joint Computer Conference. New York.

Dec. 17th: Wright Brothers Lecture. Washington, D.C.

Dec. 26th-31st: 127th Meeting, American Association for the Advancement of Science. New York, N.Y.

Jan. 8th-12th: Joint Technical Society, Department of Defense, Symposium on Thermoelectric Energy Conversion. Washington, D.C.

Jan. 9th-13th: International Congress and Exposition, Society of Automotive Engineers, Detroit, Mich.

Jan. 21st: Society of Environmental Engineers, "Development of accelerated climatic tests." London.

Feb. 7th-9th: The Society of the Plastics Industry, 16th Reinforced Plastics Division Conference. Chicago, Ill.

Feb. 15th: "The development and testing of small electronic components." London.

Mar. 16th-18th: Fifth National Conference on Aviation Education. Washington, D.C.

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The Air Force Association Convention

The Convention of the Air Force Association, which opened at San Francisco on September 21st, clarified some of the more interesting aspects of U.S. defence policy. Each year, the Convention is the scene of a mighty gathering of technicians, military personalities and all those responsible for the air policy of the most powerful nation of the free world. But this September's meeting brought to light more strikingly than ever both the problems and the brilliant achievements of America's technology.

On the opening day of the Convention, Lieutenant General Roscoe C. Wilson, USAF Deputy Chief of Staff, Development, stressed that the deterrent policy would be continued, though America was fully aware that the invulnerability of her territory could no longer depend on her natural geographical position, but only on tremendous scientific and technical effort. It would be necessary not only to "bury" the ballistic missiles of the period 1965-70, but also to resort to mobility.

But the USAF's intention is to be able to practise a policy of absolute, not of minimum deterrence. It is not merely a question of discouraging aggression by threatening the enemy's heavily populated areas; the more immediate aim, according to the old laws of war, is to be able to destroy his armed forces, including his missile sites. And General Wilson told his audience that this was the role of the B-70, which would in all probability be equipped with the *Sky Bolt*.

The combination of aircraft and airborne ballistic missile not only provided a topic for General Wilson, but also formed the background to the statements of General Kuter, Commander of North American Air Defense Command (NORAD). General Kuter demanded the rapid development of an interceptor capable of flying at Mach 3. The cancellation of the F-108 long-range interceptor programme and the reduction in the number of squadrons of F-101s, F-102s, and F-106s, deprives the anti-aircraft defence of many of its resources, for, as General Kuter told his audience, surface-to-air missiles could not be used against bombers armed only with air-to-surface missiles of the *Hound Dog* type.

General Frank F. Everest, Chief of Tactical Air Command, announced that his Staff had laid down a multi-mission tactical aircraft programme, and that the necessary development credits were included in the 1961 budget. The aircraft in question would have variable-sweep wings, on the Bell X-5 principle.

All these declarations show that both the Government and the Pentagon have categorically refused to adopt the minimum deterrence concept, under which a small number of ICBMs, threatening the enemy's cities, would dissuade any aggressor from taking up arms. Such an arsenal would be far too specialized to play any kind of role in conflicts in which the life of the American people themselves was not directly at stake. Hence the adoption of the absolute deterrence concept and the development and manufacture of a complete arsenal ranging from the tactical aircraft to the satellite via the Mach 3 bomber and interceptor, the ICBM, the tactical missile and the weapons of communications and ECM warfare.

Dr. Edward Teller, who designed and built the first American thermonuclear bomb, once again disputed the Army's arguments in favour of an anti-missile missile. The celebrated atomic scientist said that, for such a system to be of any use at all, its efficacy would have to be higher than 93 percent; in other words, it must be capable of so "filtering" enemy ICBMs that only 7 percent could get through the "filter". This statement throws a particularly interesting light on the policy of absolute deterrence—the only one which can prevent the enemy from resorting to force. For since, according to Dr. Teller, it will be impossible for many years to come to stop ballistic missiles before they reach their targets, the only solution is to adopt a defensive policy based on offensive weapons.

On this point the Convention made no startlingly new contribution. General David Wade, Commander of Vandenberg Air Force Base, merely stated that orders for the *Atlas* remain unchanged, further contracts are to be placed for an improved version of the *Titan*, and certain credits have been allocated for the development of *Midgetman* and *Mightyman* solid-propellant missiles.

As regards space warfare, which has been much discussed in the United States in recent months, General Bernard Schriever denied that the Pentagon was considering the development of anti-satellite satellites, as U.S. policy is to use space for purely peaceful purposes. It is therefore not likely that America will take any action in this field which might unleash a kind of guerilla war in space.

A new idea has crystallized from the Convention and the statements which were made there. The U.S. military authorities are manifestly preparing public opinion to accept the idea that, whatever the scientific and technical advances made by the country, safety cannot be bought at a bargain price. There is no magic weapon which can serve as the basis for overall deterrence and discourage the use of force in all aspects of war. To achieve this aim, a complete and diversified arsenal must be created for the practice of so-called absolute deterrence, whose instruments could discourage all kinds of warfare down to localized conflicts.

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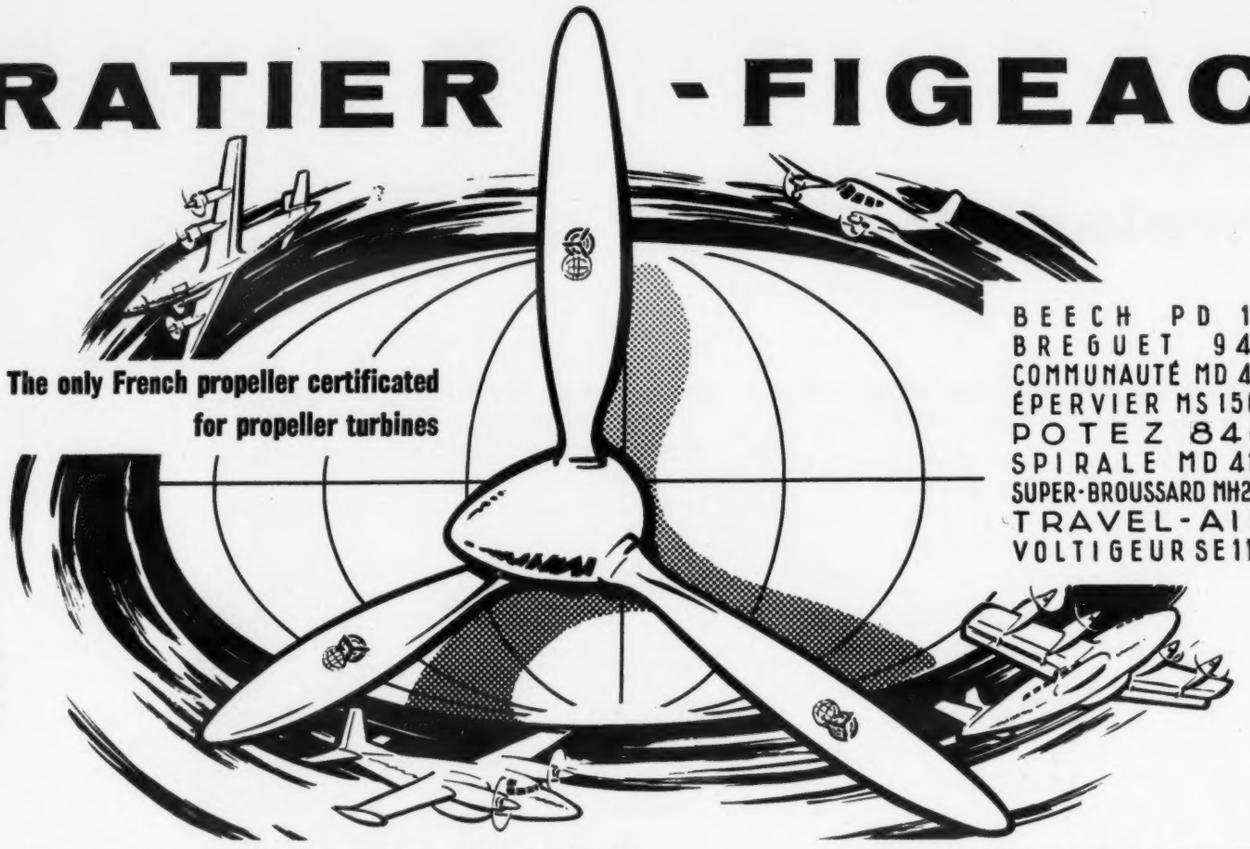

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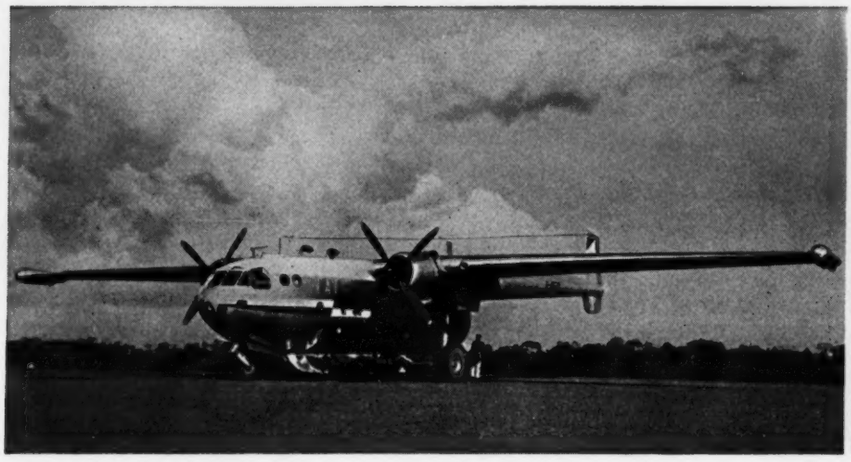

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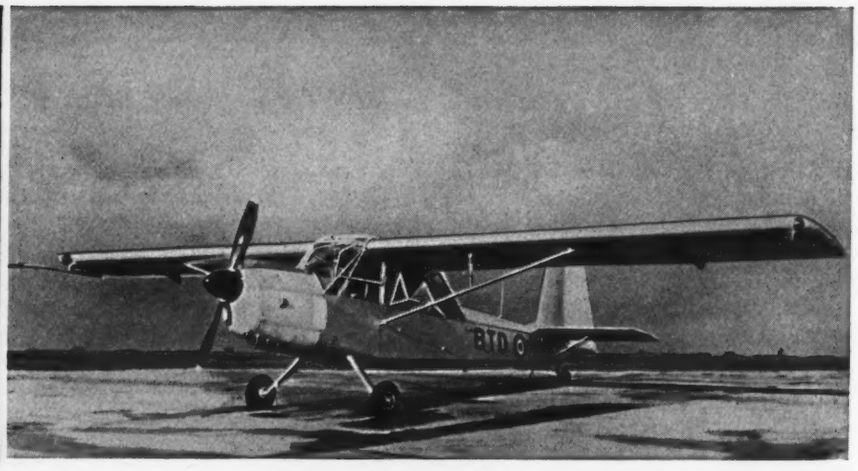

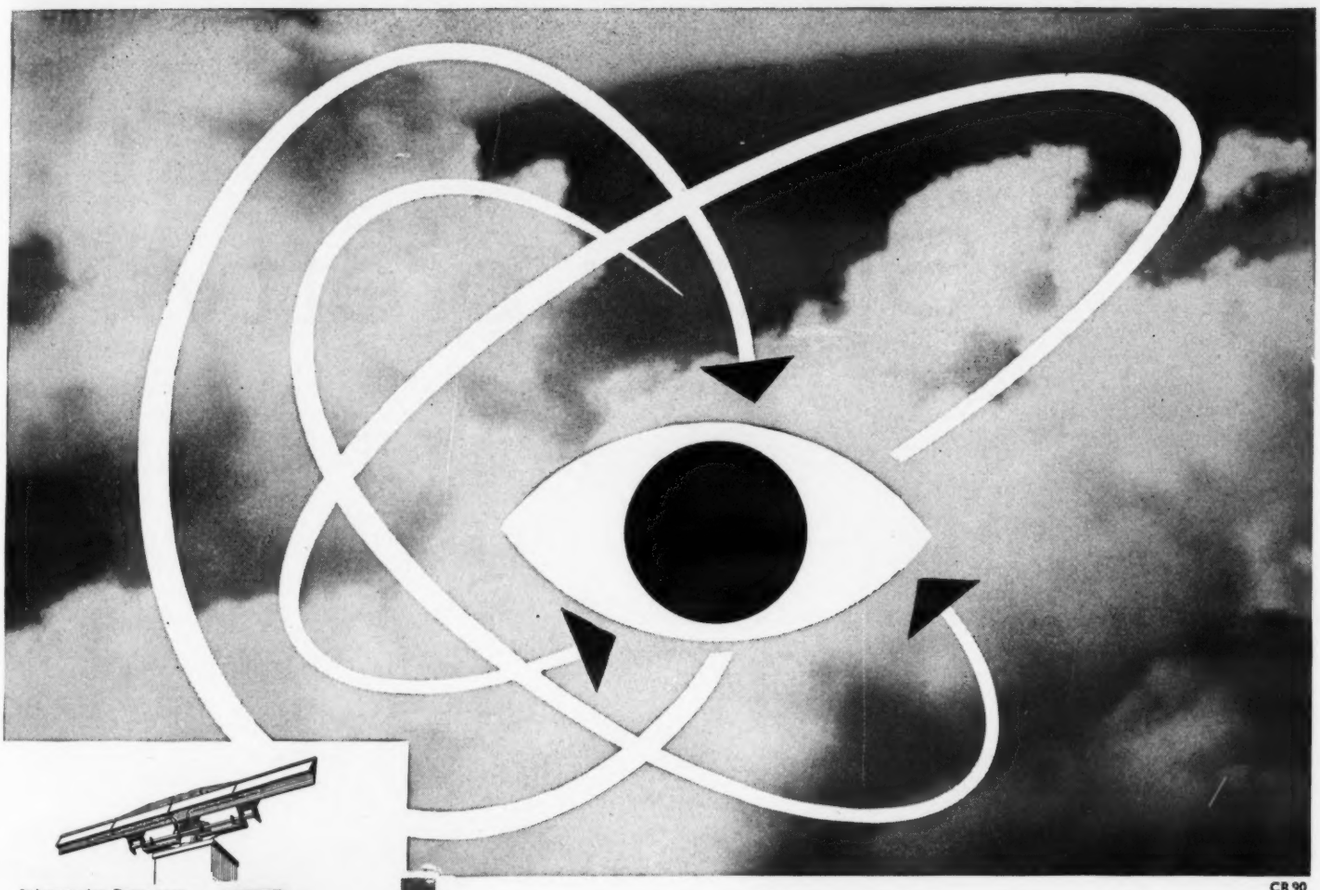

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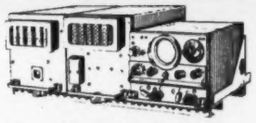

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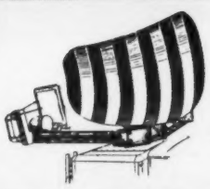

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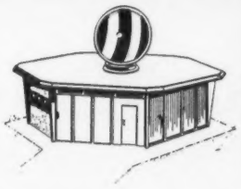

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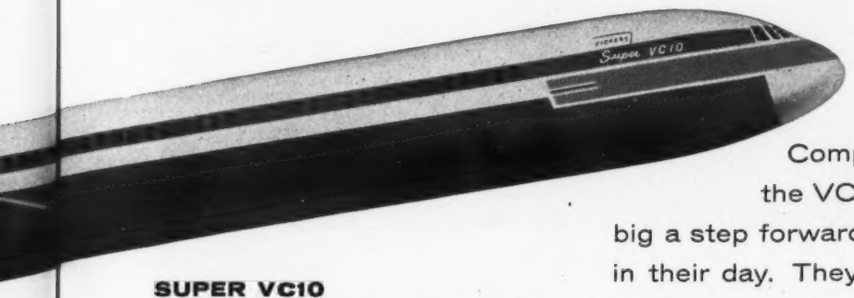

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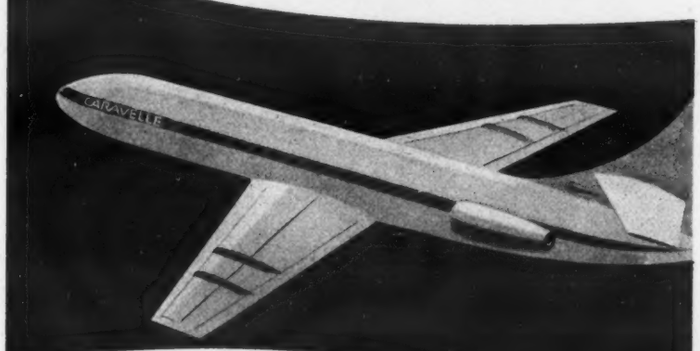

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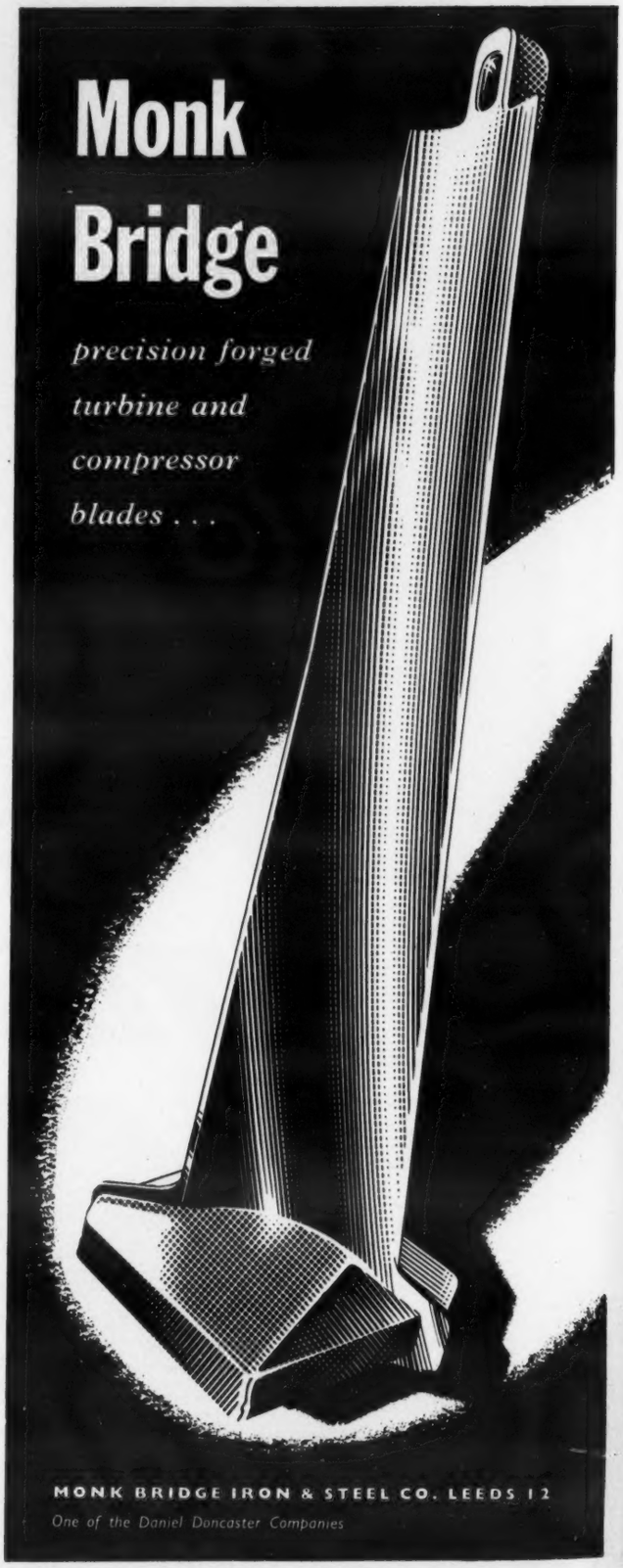

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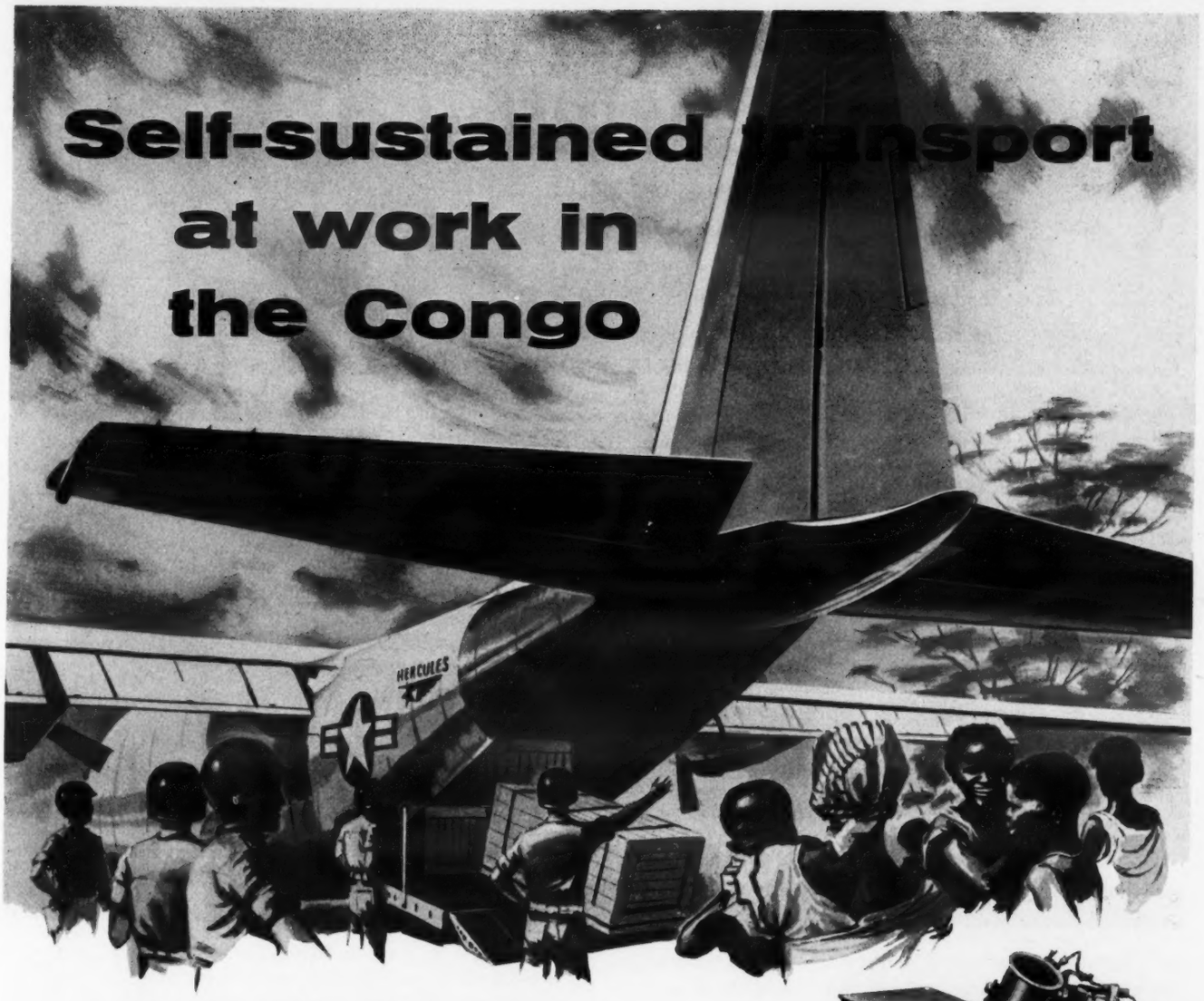
Self-sustained transport at work in the Congo



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The recent crisis in the Congo has once again proved that the self-sustained aircraft is of vital importance in transporting cargo and passengers to and from landing fields where no ground support equipment exists.

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AiResearch gas turbine compressor GTC85 is built into the left wheel well of the C-130.

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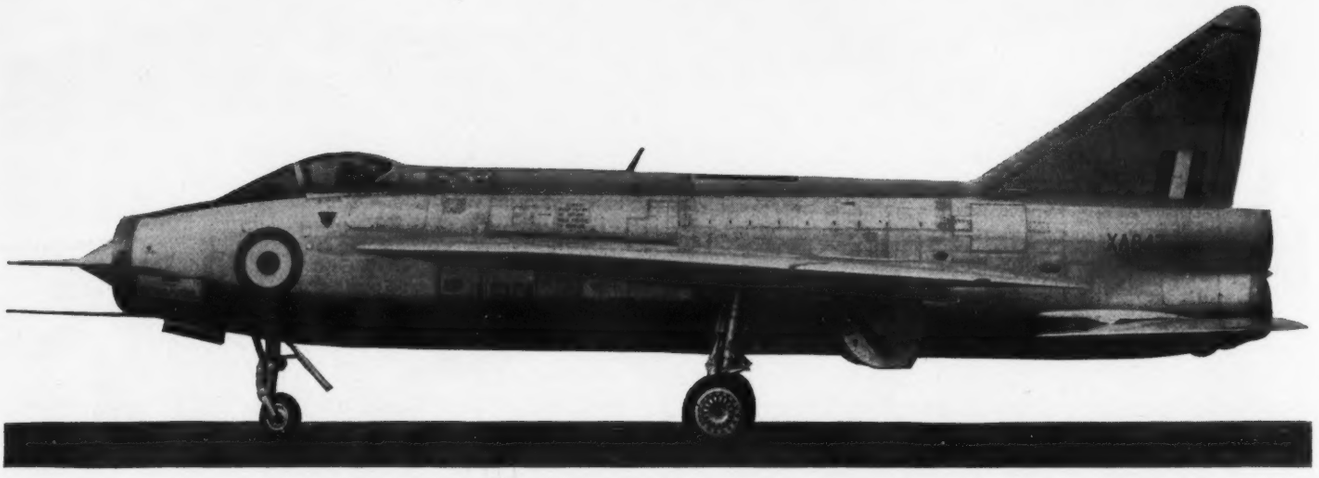

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Cold War in Infinite Space

The wind which blew across the world after the U-2 affair has again risen since the last meeting of the United Nations General Assembly. The cold war goes on. But it is already becoming clear that it will have other theatres of operations than the Middle East and the Congo.

Just as the machine-gun put an end to the serried ranks af the Napoleonic order of battle, so the new weapons of mass destruction prevent outright war between the nations which possess them. But they leave the world with limited conflicts, the use of other countries as intermediaries in the battle of ideologies, subversion, internal dissension and political warfare. And now the conquest of space offers a new field of activity for the cold war of the future.

The issues at stake are not merely scientific and technical competition and the propaganda which is its political corollary; there is also the mighty conflict of attrition which the "Big Two" are preparing and which would take the form of the mutual destruction of their satellites and space-ships.

If, in the not too distant future, an observation satellite launched from Cape Canaveral were to be "shot down" by an armed satellite fired from the Caucasus, the only result on the earth would be an exchange of protests and counter-protests. For the atomic age has seen the advent of a new *modus vivendi* between the USSR and the United States, based on the *fait accompli*. It is not so long ago that nations went to battle for no better reason than that a consul had been hit on the nose with a fly swatter or an abbreviated dispatch had been wrongly interpreted. Many a bloodthirsty war has been fought on even more futile grounds. Since Hiroshima, on the other hand, a Soviet fighter can shoot down an American military aircraft which violates a small corner of Russian airspace or, through an oversight, force a British commercial aircraft to land, without letting loose a cataclysm. And the opposite is true. If a battery of *Nikes* destroyed a Soviet aircraft in flight, the only result would be an exchange of more or less innocuous notes between the countries. It is clear to everybody that the disproportion between the crime—the shooting down of an aircraft—and its punishment—nuclear war—is so great that there is nothing to do but swallow the pill and try to get the most out of the negotiations following the event.

It is for this reason that war waged from satellites and space-ships will bestow inestimable benefits on the Power which has prepared for it and will therefore ultimately triumph. Such a conflict will wear down the enemy, demonstrate by a brilliant manoeuvre the scientific and technical superiority of the victor and serve his propaganda purposes without involving the slightest risks to either side. Belligerents in space, the two Powers will have but one weapon on earth: the verbal one. A nuclear conflict is not unleashed merely because a satellite, knocked out of its orbit, is reduced to a vapour in the upper layers of the atmosphere.

In past centuries sword and armour alternately won the day in wars of attrition, which were more or less continual and left humanity practically no breathing space. The stronghold imposed the necessity for long sieges and triumphed over the bow and lance. Later, artillery put an end to the fortress, and mobile warfare reassumed a decisive importance, until the machine-gun and field-gun in their turn led to trench war and immobile fronts. The tank again transformed the picture, and there was a return to close formation, this time with armoured units. Since Hiroshima, there has been a further sweeping revolution, for a single projectile can now wield such destructive force that both defensive strategy and wars of attrition must, it seems, be relegated to the past. There is no longer any question of filtering the enemy's onslaught through a defensive screen, nor can there be any question of a war aimed at slowly wearing down his resistance and progressively undermining his will to fight. In a few minutes, he could find himself transported several centuries into the past by the extent of the damage which he would have suffered in an infinitesimal fraction of the time which only yesterday would have barely sufficed for a skirmish.

Scarcely have the strategists begun to ponder the consequences of such a radical transformation of their customary ideas, than space warfare announces a return to the prolonged wars of attrition and to the traditional conflict between the sword and the armour, the defence and the attack. But now such battles, if they were ever to take place, would be fought hundreds or even thousands of miles above men's heads.

Because the "Big Two" each possess an almost complete array of nuclear weapons, one arsenal neutralizing the other and maintaining the *status quo* between them on earth, this new form of clash is probable, and each side must prepare for it. Nothing is easier than to build an anti-satellite satellite and place it in orbit. And it should not be impossible to fit space vehicles with anti-anti-satellite equipment. In the field of countermeasures and anti-countermeasures, electronic engineers working towards the conquest of space have vast prospects before them.

The few military thinkers who are studying the strategic implications of the conquest of space must, of course, admit that the use of the moon—or a satellite—to bombard the enemy on earth is not of primary interest. To place in permanent orbit nuclear payloads which could be hurled onto the earth as and when required offers very little promise of a solution to the problems of survival, accuracy and security posed by an effective deterrent. The only arguments habitually advanced by the advocates of the military use of space are of a philosophical, rather than a practical nature: "the side which holds the heights will win."

Setting out to explore space is certainly a paying proposition for any nation, and who knows if it will not return from its explorations with the keys to world domination? Looking for the route to India, Christopher Columbus discovered America. ↔

The International Academy of Astronautics

A Round Table for Space Scientists

By Dr. Theodore von Kármán

It is a pleasure and honor for me to write a few introductory lines for the special issue of *Interavia* dealing with astronautics. I believe it is in line with the wishes of my late great friend, the founder of *Interavia*, that an issue of his magazine should be devoted to this fast developing branch of technology, which we may call ultra-aviation or maybe meta-aviation. I do not agree with some people who say: no one is interested any more in aircraft, the era of aviation is past, the age of missiles and spacecraft is beginning. I consider the scientific and technical problems of astronautics an extension of the problems which have faced us during the past half century in aviation development. Maybe astronautics is too ambitious a term; as a matter of fact the nearest fixed star is more than four light years away from us, so that tremendous improvements in propulsion and guidance technologies would be necessary to reduce the time for the trip to a reasonable figure in comparison with the lifetime of human beings. Thus, for our generation, space flight probably will be restricted to the cislunar and planetary spaces. The expression interplanetary flight is more realistic than space flight or astronautics.

This summer the International Astronautical Federation held its eleventh congress under the chairmanship of Professor L. I. Sedov of the USSR. This congress made two decisions that promise to be of importance in the future. It approved the statutes for an International Academy of Astronautics and for an International Institute of Space Law.

Since I was charged with the task of making preparations for the establishment of the Academy by the Federation last year in London, and was designated the first Director of the Academy, I should like to speak about it in more detail.

At the first meeting of the Academy in Stockholm Professor J. Pérès, Dean of the Faculty of Science at the Sorbonne in Paris, and Dr. F. J. Malina, American astronautics pioneer, were appointed Deputy Directors. Also Professor A. Ehmert of the Max Planck Institute for the Physics of the Stratosphere in Göttingen, Germany, was appointed Chairman of Section I of the Academy for the Basic Sciences, Professor R. Pešek of the Czechoslovak Academy of Sciences in Prague to the Chairmanship of Section II for the Engineering Sciences, and Professor M. Florkin, eminent bio-chemist of the University of Liège in Belgium, to the Chairmanship of Section III for Life Sciences. Monsieur A. R. Weiller of France was appointed Acting Secretary of the Academy.

The initial membership of the Academy consists of 45 persons from the following countries: Argentina, Belgium, Bulgaria, Canada, Czechoslovakia, France, Germany, Italy, Netherlands, Sweden, Switzerland, United Kingdom, Uruguay, USA and Yugoslavia. There are nine vacancies for scientists from the USSR, allotted by the Founding Committee, which are being held open for the time being.

I should like to point out that Academicians are not chosen on the basis of their nationality, and they do not represent organizations; they are elected by members of the Academy on the basis of their personal scientific contribution to astronautics.

The statutes of the Academy authorize 60 members and 120 corresponding members for Section I (Basic Sciences); 60 members and 120 corresponding members for Section II (Engineering Sciences); and 45 members and 90 corresponding members for Section III (Life Sciences). In December next, a second third of the members for each section will be elected, and the final third a year later. After that corresponding members will be elected.

The Daniel and Florence Guggenheim Foundation of New York has made a grant of $75,000 for the Academy during the next three years for administrative and organizational expenses.

I want to emphasize again that the Academy is not a board or a committee like COSPAR (Committee on Space Research) composed of delegates of scientific societies or other similar organizations, but a meeting place for the exchange of ideas of selected individual scientists, patterned after the great classical Academies, for example, the Académie des Sciences in Paris, the Accademia dei Lincei in Rome and the Royal Society in London, with the difference that the new Academy has a strictly international character, and its activities are restricted to the newly developing sciences of astronautics.

The current program of the Academy includes editing of *Acta Astronautica*, which is published by Springer-Verlag in Vienna; choosing a recipient for the annual Daniel and Florence Guggenheim Astronautics Award; in cooperation with UNESCO giving consideration to the possibility of arranging an international symposium on "Man in Space"; and studying the question of the preparation of a multi-lingual astronautics dictionary.

The longer-range program includes work of a Joint Commission of the Academy and the International Institute of Space Law on the scientific and technical aspects of space law. This Commission is under the chairmanship of Professor J. C. Cooper of the USA, with Dr. L. R. Shepherd of the U.K. as Vice-Chairman.

The Academy has also established in Stockholm the Lunar International Laboratory (LIL) Committee under the chairmanship of Dr. F. J. Malina of the USA, with Professor E. C. B. Lovell of the U.K. as Vice-Chairman. This Committee will study the technical problems related to the construction of a scientific research laboratory on the moon.

The task of the LIL Committee may sound like science fiction. The history of aviation, however, shows many examples in which competent people severely underestimated the possibilities of practical development of this new branch of technology. ↔

Identification Parade for Space Vehicles

We are all familiar with bird watchers, locomotive and aircraft spotters . . . but so far we have not come across any satellite spotters. This is not altogether surprising; for one thing, satellites have been orbiting for only three years (*Sputnik I* was launched on October 4th, 1957, *Explorer I* on January 31st, 1958); secondly, their strange shapes and names follow no clearly distinguishable pattern; and lastly, they can be examined at close quarters only at occasional exhibitions in Moscow or Leipzig, New York or Stockholm. As if this were not enough, satellites—of which some 30 have so far been successfully launched into orbit (24 American and 6 Russian), and 14 are still "in circulation" (12 American and 2 Russian)—have been modified for every conceivable task and been joined by other artificial heavenly bodies, including three planetoids (2 American, 1 Russian) and one lunar probe (Russian). Still further special civil and military satellites, moon vehicles, unmanned space ships for longer trips—to Mars and Venus—and finally manned space vehicles are under development and will doubtless receive much attention in both the daily newspapers and the trade press in the coming decade. To introduce a little order into the maze of names and applications and to distinguish the realities of yesterday and today from the projects for the future, *Interavia* has composed the accompanying "space vehicle atlas."

This atlas divides the products and projects of astronautics into two main groups, pure research (shaded grey) and practical civil or military applications, each with five sub-groups. These break down into the following categories:

1. Early satellites

These satellites primarily served as practical proof that age-old dreams could come true, but at the same time greatly enlarged man's knowledge of geophysics and cosmology.

- *Sputnik I, II and III (USSR)*, now burned out, provided information on the density of the highest layers of the atmosphere and on phenomena in the exosphere;
- *Sputnik IV (USSR)*, still orbiting, used to test a pressure cabin;
- *Explorer I, VI and VII (USA)* proved America to be equal to the Russians and discovered, for example, the Van Allen radiation belts round the earth;
- *Vanguard I, II and III (USA)*, the only successful examples of a long series of projected dwarf satellites with miniaturized instrumentation; very long life, extending in the case of Vanguard I (whose transmitters, fed by solar batteries, are still operating) to several centuries.

2. Early planetoids

- *Lunik I (USSR)*, originally designed to circle the moon, missed its way and is now orbiting the sun once in 15 months;
- *Pioneer IV (USA)*, orbits the sun in roughly 13 months, transmitted during the first 100 hours;
- *Pioneer V (USA)*, orbits the sun in 312 days, is equipped to measure radiation in interplanetary space, but its transmitter (fed by solar batteries) has ceased operation.

3. Lunar probes

- *Lunik II (USSR)*, made a hard landing on the moon;
- *Lunik III (USSR)*, transmitted the first television pictures of the other side of the moon to Moscow and is still circulating around the earth.
- *Future projects*—so far as known—include the *Ranger*, *Surveyor* and *Prospector* unmanned lunar vehicles and the *Apollo* manned vehicle (all USA).

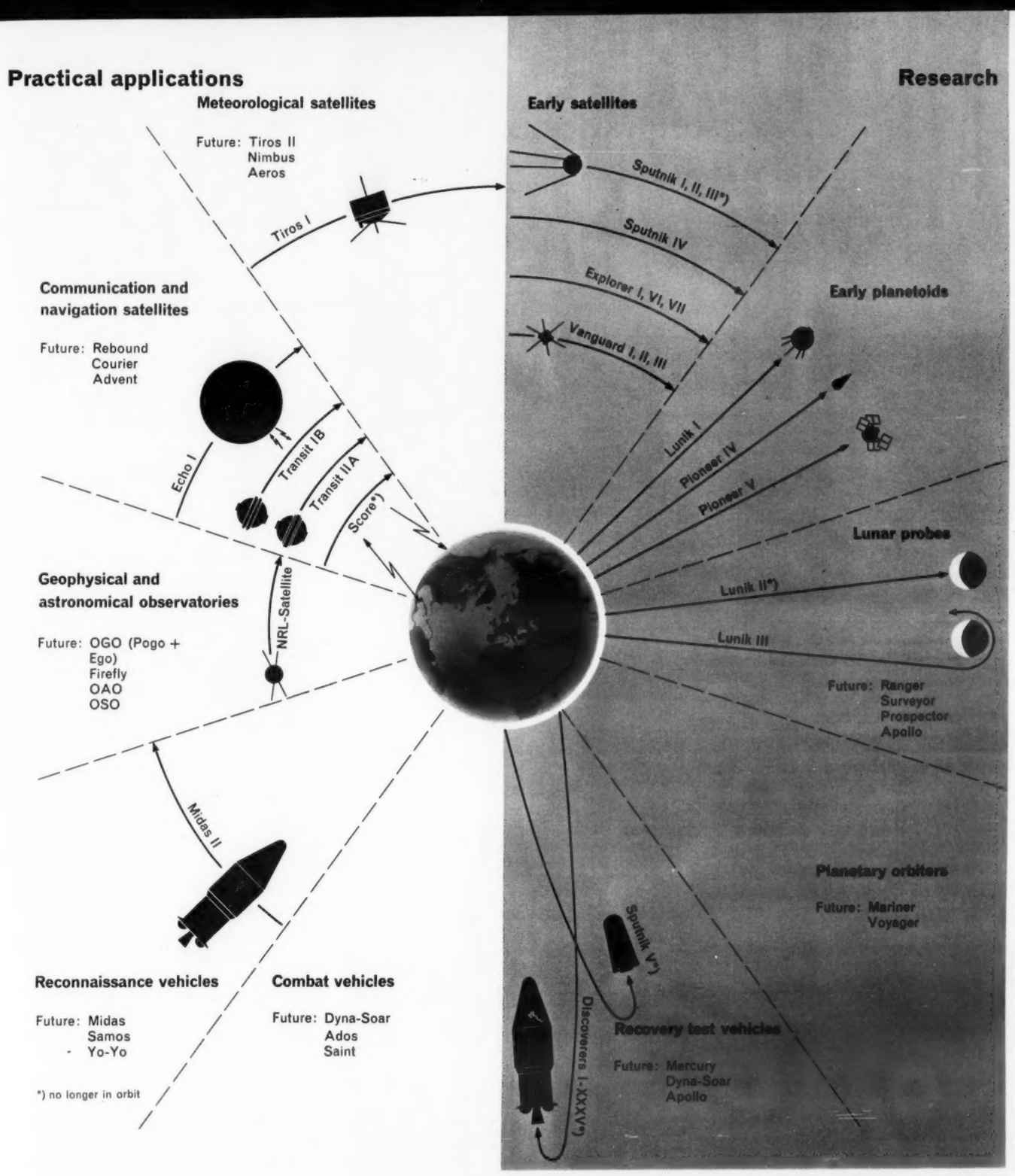
4. Planetary orbiters

- *Future projects*, such as *Mariner* (USA) and *Voyager* (USA), for trips to Mars and Venus.

5. Recovery test vehicles

Constructed as separable portions of special satellites, the recovery vehicles already tested or projected for future tests are designed to prepare the way for the safe recovery of instruments, animals and ultimately men.

- *Discoverers (USA)*, of which 15 have so far been launched (another 20 launchings are planned); in two cases (*Discoverer XIII* and *XIV*) the capsule was recovered, once from the Pacific, the second time in the air (captured by a C-119);
- *Sputnik V (USSR)*, brought two dogs (Strelka und Byelka) safely back to earth on August 20th, 1960, after the 17th orbit.
- *Future projects* (all USA) include a series of single-seat *Mercury* recovery capsules and *Dyna-Soar* space gliders, as well as experimental versions of the three-man *Apollo* space ship.



6. Meteorological satellites

- *Tiros I (USA)*, abbreviation for *Television Infra-Red Observation Satellite*, is the first weather satellite, equipped with two television cameras which transmitted more than 22,000 pictures back to earth (see separate article);
- *Future projects* (all USA) include additional *Tiros* vehicles and the more advanced *Nimbus* and *Aeros* satellites, the latter with 24-hour equatorial orbits which will make them appear stationary in relation to the earth.

7. Communications and navigation satellites

The former are designed for passive (reflection) or active (relay station) transmission of ultra-short waves over global distances; the latter are to enable ships at sea to determine their positions with a high degree of accuracy by the Doppler principle.

- *Score (USA)*, abbreviation for *Signals Communications Orbital Relay Experiment*, now burned out, played back on command messages transmitted to it during orbit;
- *Transit IB and IIA (USA)*, navigation satellites; the latter is still transmitting (on 4 frequencies) and is equipped with a time base (electronic clock);
- *Echo I (USA)* passive communications satellite 100 ft in diameter, visible to the naked eye at night;
- *Future projects* designated *Rebound*, *Courier* and *Advent* (all USA).

8. Geophysical and astronomical observatories

- *NRL satellite (USA)*, an instrumentation package launched with *Transit IIA* (as double satellite) to measure given bands of solar radiation;
- *Future projects* (all USA) with less colourful abbreviations such as OGO (Orbiting Geophysical Observatory), OAO (Orbiting Astronomical Observatory) and OSO (Orbiting Solar Observatory); also *Firefly* for geodetic purposes.

9. Reconnaissance vehicles

- *Midas II (USA)*, abbreviation for *Missile Defense Alarm System*, forerunner of a series of American early warning satellites designed to detect Soviet ballistic missiles immediately after launching, with the aid of infra-red sensors, and to report on their launching by radio;
- *Future projects* include further *Midas* satellites, also the *Samos* (Surveillance and Missile Observation Satellite) and the *Yo-Yo* tactical reconnaissance satellite for the U.S. Navy.

10. Combat vehicles

- *Projects only at present*, such as the *Dyna-Soar* (manned space bomber/reconnaissance vehicle), *Ados* (Astronautical Defensive-Offensive System) and *Saint* (Satellite Interception).

Saturn

Backbone of the U.S. Space Programme

If, despite America's impressive achievements in the space race, U.S. prestige has suffered so many setbacks, this is due to a single, yet decisive cause: the lack of boosters for heavy payloads. Although the Americans undoubtedly have the lead over the Russians as regards the number of successful satellite and space probe launchings, although the many-sidedness of the U.S. space programme cannot fail to impress, the fact remains that the USSR has rockets which are not only larger, but also more reliable. It is therefore understandable that the development of high-thrust boosters is at the core of the USA's ten-year space research programme. It is perfectly clear to the Americans that the Russians have no intention of resting on their laurels; on the contrary, they are more likely to speed up the pace of development. A "sustained" American development programme would thus have no prospects of lessening the gap between the USA and the Soviet Union; only a sudden spurt could enable the United States to equal or surpass Soviet rocket techniques.

But the mere recognition of this self-evident fact is of little use. The thorniest problem lies in determining the optimum effort to be put into the spurt. If the sights are set too high, then there is an increased risk that the conditions necessary to attain the goal will not be met in time. With an over-cautious programme, on the other hand, progress will be imperceptible. To find the compromise between the two contradictory requirements, "highest possible rate of development" and "lowest possible risk," demands not so much specialized scientific knowledge as a wide experience in the field of rocket techniques and the organization of the research work necessary to gain it. It is therefore hardly surprising that the concept on which the U.S. Government finally decided originated with Wernher von Braun, who is more qualified than any other to meet the requirements described above. He is backed up by a team of engineers who during World War II brought rocket techniques to the stage which was more or less the common starting point for both American and Soviet post-war development.

While, in the post-war years, the Americans were content to use captured V-2s for upper atmosphere research, the Soviets lost no time in developing boosters for nuclear warheads on the basis of German achievements. The initially high weight of these warheads—of the order of two tons—compelled the Russians to base their development programme on high launching weights and correspondingly high thrusts. It was only later that the USA began to develop ballistic rockets, since the miniaturization of nuclear warheads, already under way, meant that payload weights could be substantially reduced. It thus appeared less urgent to increase the thrusts of rocket motors.

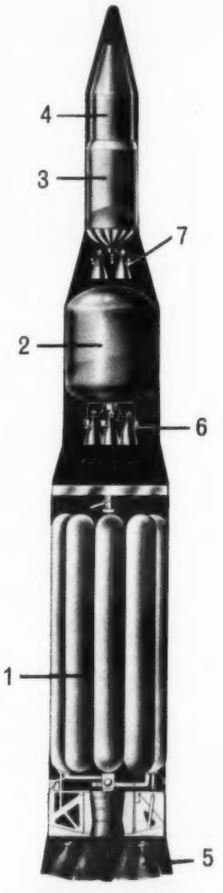


Diagram of the C-1 three-stage version of Saturn. 1 – First stage with nine cylindrical propellant tanks (kerosene and liquid oxygen); 2 – second stage, under development at Douglas; 3 – third stage, a modified Convair *Centaur;* 4 – payload; 5 – eight Rocketdyne H-1 rocket motors, each delivering 188,000 lb thrust; 6 – four Pratt & Whitney XLR 115s, each with 17,500 to 20,000 lb thrust; 7 – two XLR 115s.

American statesmen made their major error when they gave exaggerated priority to the U.S. Navy's *Vanguard* project in allocating funds for research. Wernher von Braun, developing rockets for the U.S. Army with his former Peenemünde colleagues, urged in vain that priority should be given to projects based on his rockets. The failure to recognize the political significance of successful space research still dogs U.S. efforts. As will be recalled, it was the *Redstone,* developed by von Braun, which placed the first American satellite in orbit on January 31st, 1958.

From Project to Programme

As early as the spring of 1957, half a year before the launching of the first Russian *Sputnik,* Wernher von Braun was working on preliminary studies for a rocket first stage with clustered engines. The project initially envisaged four Rocketdyne engines of 360,000 lb thrust each—the most powerful under development at that time. On the basis of von Braun's studies, the Army Ballistic Missile Agency (ABMA) recommended, in December, 1957, the development of a booster of 1.5 million pounds thrust. Despite the Soviet lead, which was by now unmistakable, a further nine months elapsed without a decision being reached. Finally, in August, 1958, the Advanced Research Projects Agency of the Department of Defense ordered ABMA to initiate a development programme for a giant booster, though with the proviso that it should be "based on rocket engines presently available." Since five to seven years normally elapse between the initial design of a booster and the time when it becomes operational, it was out of the question to burden the programme with the development of a new rocket engine. These considerations led the Advanced Research Projects Agency to modify its original four-engine design in

favour of one with eight engines, each delivering 150,000 lb thrust.

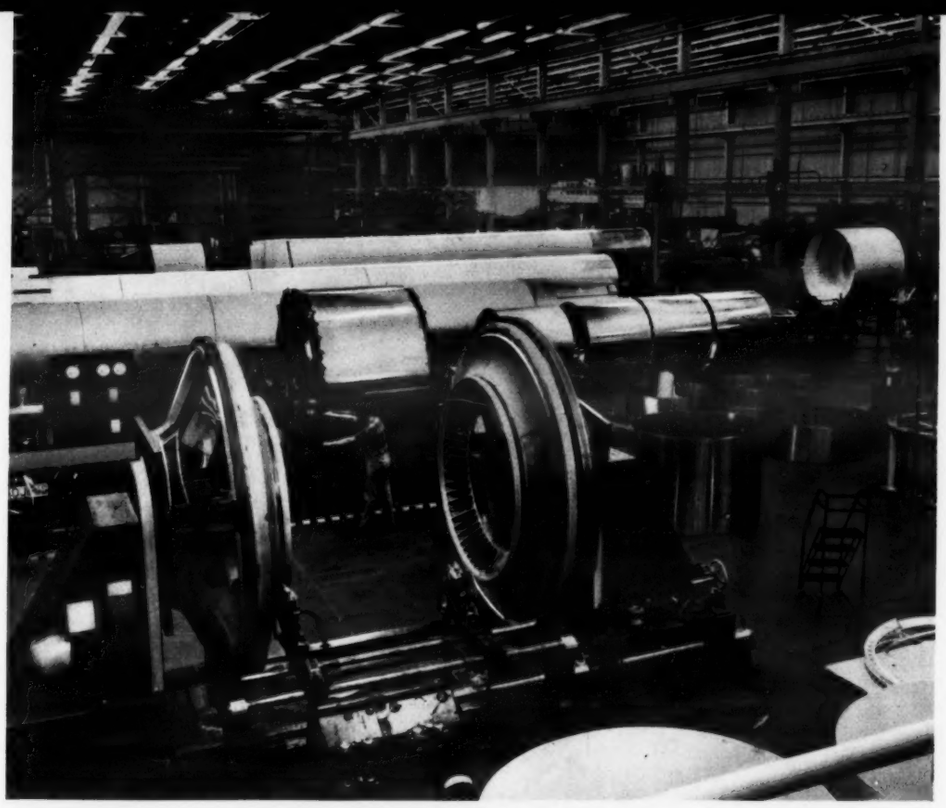
Engines of this thrust class were already in production for the *Thor* and *Jupiter* IRBMs. In September, 1958, Rocketdyne received a contract for further engine development, with particular emphasis on simplification of design.

Two months later, Wernher von Braun's team in Huntsville, Alabama, received orders to build four experimental vehicles. The rocket test rig at Huntsville had to be converted for 1.5 million pounds thrust. At last, in April, 1959, work began on the construction of a launching pad at Cape Canaveral.

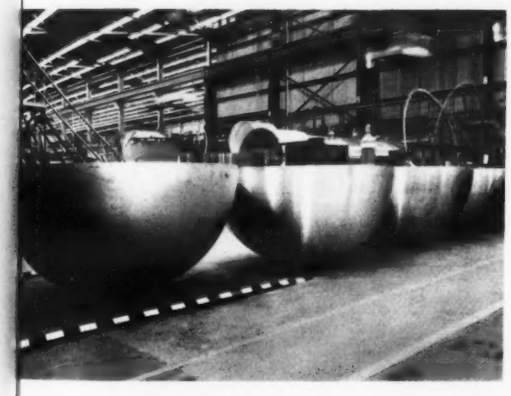
The *Saturn* project did not, however, gain a firm foothold in the U.S. space programme until, in November, 1959, President Eisenhower handed over the responsibility for the project to the National Aeronautics and Space Administration. As a result of this decision, ABMA's personnel and facilities at Huntsville were incorporated into NASA on July 1st, 1960 and today, under the name George C. Marshall Space Flight Center, form its most heavily staffed division.

In the meantime, the first booster had been completed and was mounted on the test rig in February, 1960. After test runs with first two, next four and then six engines working simultaneously, all eight engines were fired for the first time in April.

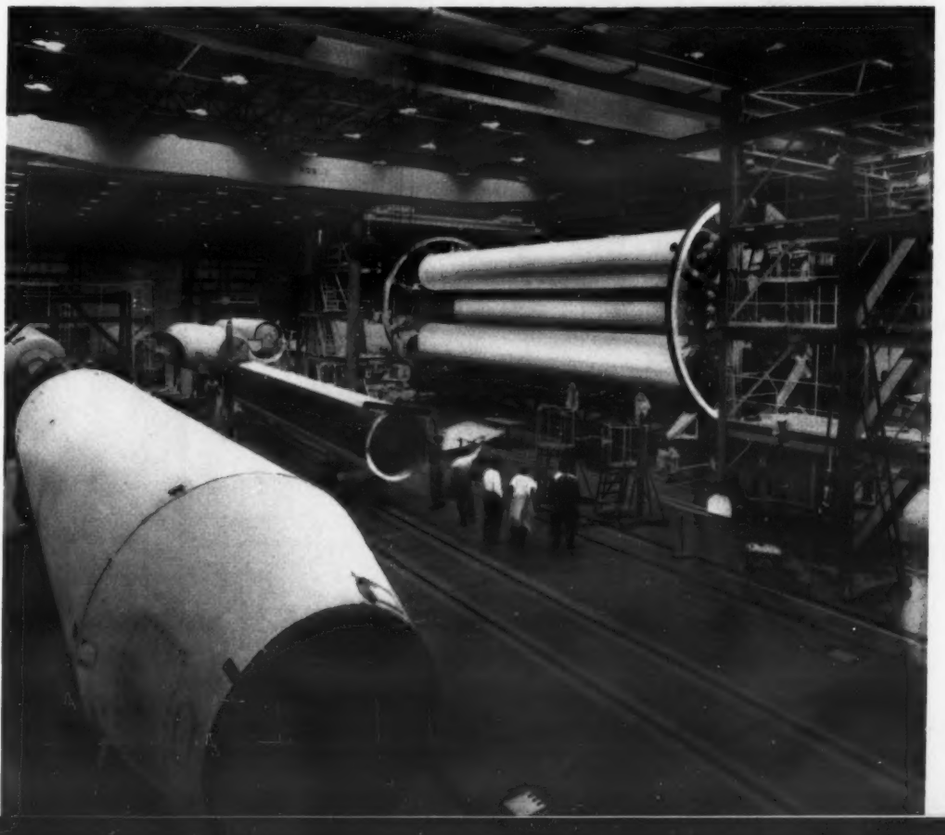
NASA's *Saturn* programme is based on the requirement for maximum simplicity. No doubt there is an optimum booster for each of the many tasks of space research. But scientists are still far from being able to produce a booster like a rabbit out of a hat, a vehicle which will be fully operational after a few "test flights." A successful launching must be preceded by an incredible number of processes carried out in a definite order and with split-second timing. In the case of the *Juno II* with an earth satellite as payload, for instance, these processes number 144. The breakdown of any one of them jeopardizes the entire operation. The failure of one launching, for example, was traced to defects in two small components worth only $100 between them. A production fault and an unreported modification resulted in a loss of five million dollars. Small wonder that Major General Don R. Ostrander, NASA Director of Launch Vehicle Programs, laid down the following guiding principles for further rocket development: "Reduce to a minimum the



Construction of the Saturn first stage at NASA's George C. Marshall Space Flight Center.
Propellant tank sections being welded together; welding equipment in foreground.



End bulkheads for the external tanks. Each bulkhead is made from a single piece of metal by a combined chemical-mechanical process.



After the five oxygen tanks have been attached together, a kerosene tank is about to be fitted. The rings at the end of the booster are for installation purposes and simplify handling during transport. They are not removed until the rocket is on the launching pad.

Technical Data:

Booster	No. of stages	Length	Launching weight	Typical payloads
Saturn C-1	3	185 ft	~ 1,200,000 lb	22,000 lb into a 300-mile earth orbit 12,000 lb around the moon (instrument capsule) 9,000 lb into interplanetary orbit 4,500 lb into 24-hour earth orbit 2,400 lb for soft landing on moon *Rover* nuclear rocket as third stage
Saturn C-2	4	213 ft		45,000 lb into a 300-mile earth orbit 17,000 lb into interplanetary orbit 9,000 lb into 24-hour earth orbit 5,000 lb for soft landing on moon Manned capsule around moon
Saturn C-3 (development doubtful)	5	over 230 ft		55,000 lb into earth orbit Soft landing of manned capsule on moon and return to earth

Stage				Engines			
Designation	Manufacturer	Length	Diameter	No. and designation	Manufacturer	Propellant	Thrust
S-1	NASA	82 ft	21 ft 8 in	8 × H-1	Rocketdyne	RP-1 plus lox	8 × 187,500 lb = 1,500,000 lb
S-2	—	—	—	4 × J-2 (6 × J-2)	Rocketdyne	Liquid hydrogen plus lox	4 × 200,000 lb = 800,000 lb 6 × 200,000 lb = 1,200,000 lb
S-3	—	28 ft	—	2 × J-2 (4 × J-2)	Rocketdyne	Liquid hydrogen plus lox	2 × 200,000 lb = 400,000 lb 4 × 200,000 lb = 800,000 lb
S-4	Douglas	50 ft	18 ft	4 × XLR 115	Pratt & Whitney	Liquid hydrogen plus lox	4 × 17,500 lb = 70,000 lb (planned thrust increase to 4 × 20,000 lb = 80,000 lb)
S-5	Convair	53 ft	10 ft	2 × XLR 115	Pratt & Whitney	Liquid hydrogen plus lox	2 × 15,000 lb = 30,000 lb (planned thrust increase to 2 × 20,000 lb = 40,000 lb)

number of different types of vehicles and components that are developed and thereby increase the frequency with which those that remain are used. This rule applies all down the line from vehicles to stages, to engines, and to the very smallest components. We hope eventually to arrive at a fleet of standardized vehicles whose realiability will more than offset the disadvantage of using vehicles on specific missions for which they may not be optimum."

As before, a large proportion of the research and development work consists of practical tests, first on the rig, and then in the form of trial firings. To cut costs, it is planned to recover the *Saturn* boosters after launching. Air brakes, parachutes and finally retro-rockets which fire just before the rocket plunges into the ocean, will reduce the impact speed almost to nil, so that no main components are damaged. When its tanks are empty, the *Saturn* first stage will float. In this way, NASA technicians hope to make do with only ten experimental vehicles until *Saturn* becomes operational.

Three versions

According to information so far released, *Saturn* will be built in three versions: the three-stage C-1, the four-stage C-2 and the five-stage C-3 *(see table)*. By a logical application of the "building block" principle, each later version will grow out of the previous one by the addition of a single new stage. The first stage is the same for all versions. It is designated S-1 and consists of eight Rocketdyne H-1 engines, each delivering 188,000 lb thrust. With a burning phase of 120 seconds, this gives the mighty impulse of 2,256,000 lb/sec. The fuel is RP-1 (kerosene), the oxidizer liquid oxygen. The second stage of C-1 bears the designation S-4[1] and will be powered by four Pratt & Whitney XLR 115 engines[2] giving a total thrust of 80,000 lb. The third stage, S-5, will be built by Convair; it will be a modified *Centaur* upper stage with two XLR 115 engines.

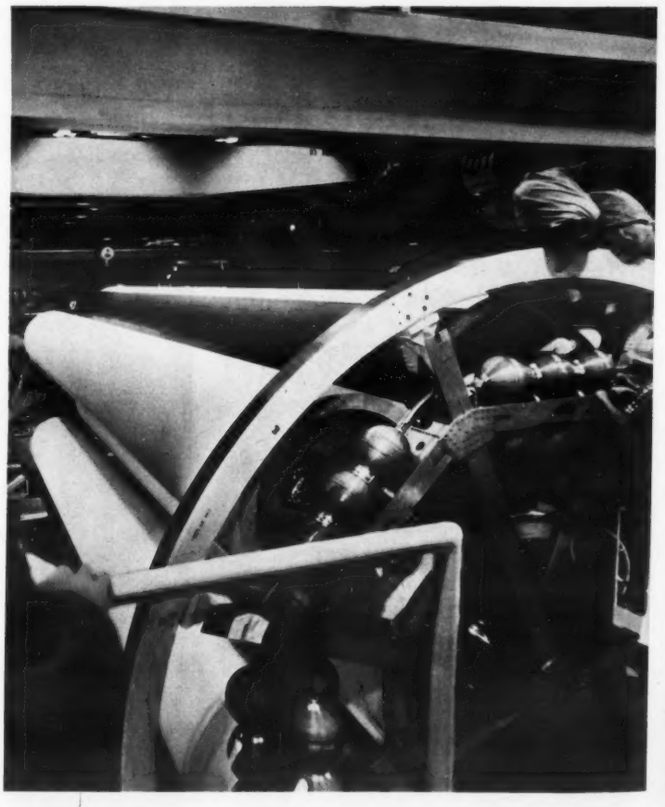
A very high energy fuel, liquid hydrogen, has been chosen for all the upper stages of *Saturn*. Given the present state of the art, the tasks allotted to the U.S. space programme can be carried out with chemical rockets only if the upper stages use such fuels. In addition, it has been demonstrated that the lower stages of a space vehicle designed for interplanetary missions provide the optimum boosters for missions near the earth. The *Saturn* programme therefore lays considerable stress on adaptability and extensibility.

At the moment, a firm development contract has been placed only for the C-1. The C-2 is still on the drawing board, although Rocketdyne recently received a contract to develop the engine for the new second stage.

The C-3 version has still not yet passed beyond the project stage. It is, indeed, doubtful whether it will ever be built. Nuclear powerplants or engines such as the Rocketdyne F-1, one of which delivers the same thrust as the whole *Saturn* first stage, could open up new lines of development. The fact that they are restricting themselves to only three engine types with only two different combinations of propellant shows, however, that the Americans are taking the question of simplification very seriously. Admittedly, other projects are still being investigated on paper,

[1] The figure after the "S" denotes the position which the stage will occupy in the five-stage C-3.

[2] Cf. *Interavia* No. 2/1960, page 168 et seq.



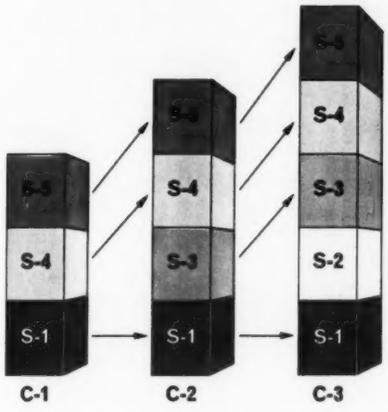
A giant frame in the form of a spoked wheel, built of aluminium alloy 7075, forms the connecting link with the second stage. The spheres contain a rare gas, with which the kerosene and liquid oxygen tanks are kept under pressure.

but parallel developments are finding no favour with the authorities.

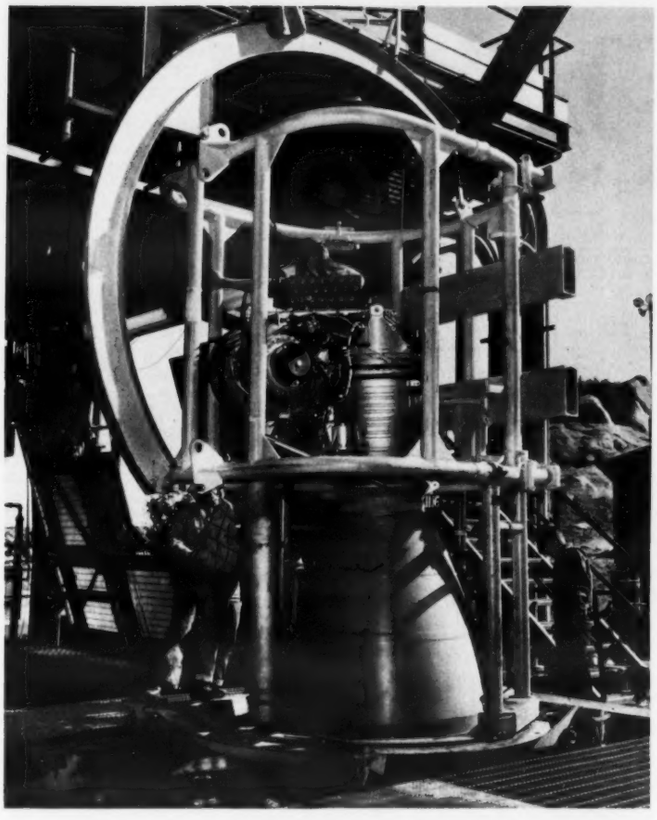
The first stage

The *Saturn* first stage is the largest thrust unit ever to be built ... at any rate in the West. There are no official data on Soviet boosters, though American experts estimate their thrust at 600,000 to 800,000 lb.

As booster size grows there is an increase not only in cost, but also in problems. Keeping 1.5 million pounds thrust under control is setting the technicians in Huntsville new tasks every day.



The "building block" system for minimum development costs. Even in the basic C-1 version, the third stage is being taken over from the *Centaur*, which is already in an advanced phase of development. The insertion of a new stage, S-3, gives the four-stage C-2 version, and the addition of S-2 the five-stage C-3.



The H-1 liquid rocket engine with 188,000 lb thrust on the test stand of North American's Rocketdyne Division. Powered by eight H-1s, the first stage of *Saturn* will deliver 1.5 million pounds thrust, about four times as much as the most powerful U.S. booster in existence today.

The particular difficulty in the case of the S-1 is that it is designed for a variety of tasks and is intended to operate with different combinations of upper stages and payloads—many of which have not yet been decided on. Centre of gravity, inertial moments, distribution and strength of the air forces, and track accelerations change with each new combination. Structure and powerplant must therefore be so designed that they do not constitute an impediment to further development.

The George C. Marshall Space Flight Center at Huntsville is not only responsible for the development and testing of *Saturn*, but also plays an active part in its construction. With the completion of the last *Jupiter* in July, 1959, the Center's facilities became free for further activities and could at once be converted to build the S-1. Right from the start, construction of this version was geared to the tools and equipment already available. The propellant tanks have the same diameters as those of the *Jupiter* and *Redstone;* from the construction point of view, their greater length requires fewer drastic changes.

The S-1 will carry 750,000 lb of propellant in nine cylindrical tanks. Around a central tank with a diameter of 105 inches are arranged eight tanks, each with a diameter of 70 inches. The central tank and four of the outer tanks contain liquid oxygen, the remaining four outer tanks kerosene. Cross-feed circuits between the two groups of tanks permit equalized filling and emptying and the diversion of propellants if one engine breaks down. The aft ends of the tanks are attached to an eight-legged thrust frame, which also supports the eight engines, arranged symmetrically around the stage's longitudinal axis in two groups of four.

The thrust vectors of the rigidly attached inner engines make angles of 3° to the booster axis. The outer engines serve for thrust vector control and can be turned through angles of about 10° by means of inertial guidance systems and hydraulic cylinders. In their normal position they are inclined at an angle of 6° to the axis. Each engine forms an individual unit with its gas generator, pumps, starter and regulators.

The tanks are of aluminium alloy. The contour-milled tank walls are rolled into cylinders and welded together. Stiffening rings, perforated to form anti-slosh baffles, keep the walls from buckling. Finally, the hemispherical end bulkheads are mounted. The tanks are assembled with the aid of two tool rings, which are not removed until the vehicle is on the launching pad. Their rigid construction enables the tanks to transmit acceleration forces directly to the second stage. As, however, the oxygen tanks contract almost 2½ inches when filled (owing to cooling), only one group of tanks, either the oxygen or the kerosene tanks, can be used for carrying the thrust forces to the upper stages. The decision was taken in favour of the oxygen group, which also includes the central tank.

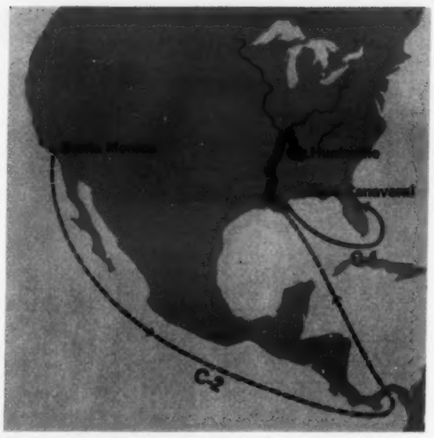
Reliability

The trajectory of a ballistic vehicle in a given field of force is determined by its attitude and speed on burnout, and the slightest deviation from the calculated path jeopardizes the success of the entire operation. Tolerances for a ballistic rocket designed to impact on the moon, for instance, are of the order of 150 m/sec burnout speed and 20 minutes of arc attitude. There are, of course, unforeseeable circumstances, such as meteorite impacts or radiation pressures, for which no provision can be made. Fluctuations in air forces can be countered by thrust vector control, as the rocket has normally penetrated beyond the atmosphere by the time its engine has burnt out. As the number of simultaneously firing engines increases, the probability of breakdown in one engine rises. This reduced reliability is, however, more than offset if the booster can carry out its mission even after the breakdown of one (or more) engines. Here the considerations regarding the optimum number of engines are similar to those which apply to aircraft. In *Saturn*, it is the upper stages which put the payload capsule onto a precise trajectory; the first stage serves merely to penetrate the denser

layers of the atmosphere, and the tolerances for attitude and burnout speed can therefore be fairly wide. Even if one of the engines ceases to function immediately after launching, the inertial guidance system, operating via the swivelling engines, will keep the thrust vector within the necessary tolerances. In many cases the subsequent breakdown of a further engine can also be corrected.

Among the most formidable sources of error in rockets are the starter and ignition devices. In place of the usual conglomeration of pneumatically actuated valves, relays and switches, the *Saturn* has a simple starter system actuated by a single electrical signal. To protect the structure of the rocket from the sudden shock of 1.5 million pounds thrust, the eight engines are not started simultaneously, but in pairs, at intervals of a quarter of a second. To avoid asymmetrical forces, engines lying opposite each other are paired for starting. The electrical pulse first ignites a small solid-propellant motor, whose exhaust gases accelerate the turbopump to its rated speed in a fraction of a second. When operating pressure is reached, the propellant valves automatically open, leaving the way clear to the combustion chamber. At the same time, a small quantity of aluminium triethyl is injected into the combustion chamber and instantaneously ignites the engine. Each engine reaches its lift-off thrust within half a second, and less than two seconds elapse between the ignition of the first pair of engines and the moment the rocket leaves the ground. If the pressure in one of the combustion chambers does not reach the required level on starting, the engine turbopump is automatically shut down and the propellant feed system blocked. A sequence switch system then turns off the other engines.

The H-1 engine is more simple than its predecessors. In a single stage of development



The "terrestrial" trajectory of the first and second stages of Saturn. The first stage is assembled at Huntsville and then transported down the Tennessee, Ohio and Mississippi and through the Gulf of Mexico to Cape Canaveral (solid line). The second stage is first taken from Douglas Aircraft Company's assembly line to Huntsville (dotted line), there it is tested and prepared for operation before likewise being sent to Cape Canaveral (solid line).

—from the S-3D of *Jupiter* to the H-1 of *Saturn*—it was possible to reduce the number of main components to a tenth. Here it should be mentioned that the turbopumps are mounted on the swivelling combustion chambers, so that only the low-pressure, and not the high-pressure, lines need be of flexible construction.

Space vehicles are "bulky" goods

Paradoxically enough, *Saturn*, a vehicle designed for journeys millions of miles long, presents some very knotty problems when it has to travel on the surface of the earth. With its diameter of 21 ft 8 in. and length of 82 ft, the first stage is a piece of merchandise which may indeed be qualified as "bulky." It is not so much the length as the diameter which makes normal means of land and air transport impossible. This leaves only transport by water, which is, fortunately, near at hand: the Marshall Space Flight Center, where the first stage is assembled, lies not far from the navigable Tennessee River, a tributary of the Ohio.

On a barge specially constructed for the purpose, the booster will be floated down the Tennessee, Ohio and Mississippi into the Gulf of Mexico and around the Florida peninsula, finally reaching Cape Canaveral via the Banana River—a 2,200 mile journey lasting three weeks. The distance between Huntsville and Cape Canaveral as the crow flies is, incidentally, 600 miles. The S-1 could, it is true, be transported by air in sections, but it would then have to be reassembled on the launch pad, a procedure which would require further test runs, checks, pressure tests and similar costly and time-wasting work. Transport by water is still the cheapest solution.

An even longer Odyssey awaits the second stage of *Saturn*. Assembled at Douglas's Santa Monica plant in California, it will be brought by ship through the Pacific, the Panama Canal, the Gulf of Mexico, the Mississippi, Ohio and Tennessee to Huntsville, there checked and prepared for operation, and finally—as above—transported to Cape Canaveral—a journey of 10,000 miles.

Quantity production in 1964

After a series of static test runs, *Saturn* will undergo tests on a "dynamic rig." This installation will be used to train maintenance crews, study assembly problems, make vibration and flexing measurements and investigate the behaviour of cryogenic liquids during lengthy storage.

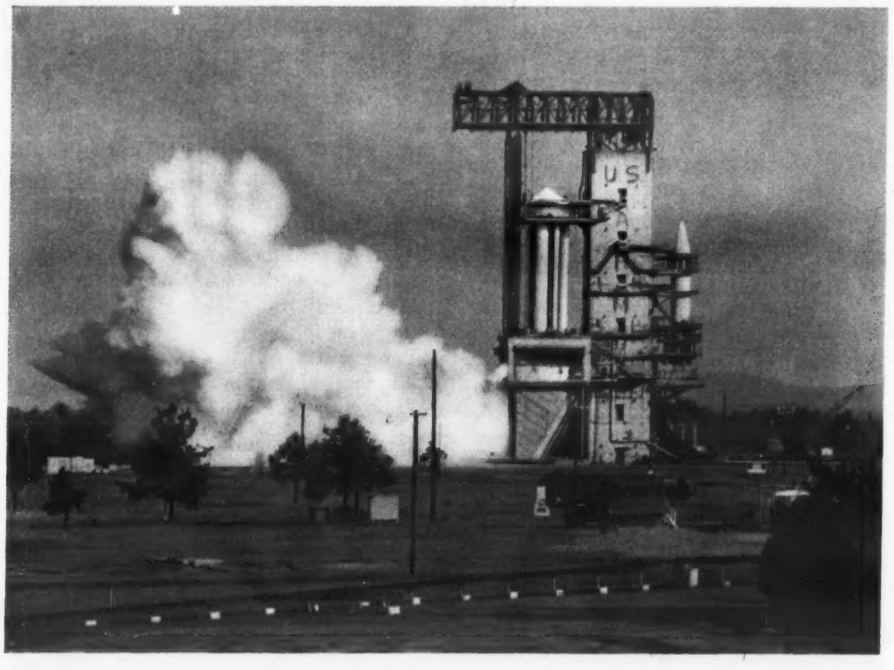
The first launching of a *Saturn* first stage is scheduled for the second half of 1961. To simulate the dynamic conditions occurring with a complete vehicle, the rocket will carry full-scale dummies in place of the upper stages. The next two experimental vehicles, to be launched in 1962, will still have dummy upper stages. For all three tests it is planned to fire the engines with decreased thrust (about 1.3 million pounds).

Test vehicle number 4, which will be the first to operate on full thrust, will have a genuine second stage and a dummy third stage. The seventh test vehicle will have all three stages. The launching programme is as follows:

Vehicle	Number of tests			
	1961	1962	1963	1964
S-1 + dummies	1	2		
S-1 + S-4 + dummy		1	2	
S-1 + S-4 + S-5			3	
Prototype of production *Saturn*				1

If all goes well, from 1964 onwards NASA, and with it the Western world, will have in *Saturn* a versatile and extensible booster for high payloads, giving space research a "new impetus"—in the fullest sense of the word.

The eight engines of the *Saturn* first stage being test run at the George C. Marshall Space Flight Center at Huntsville, Alabama.



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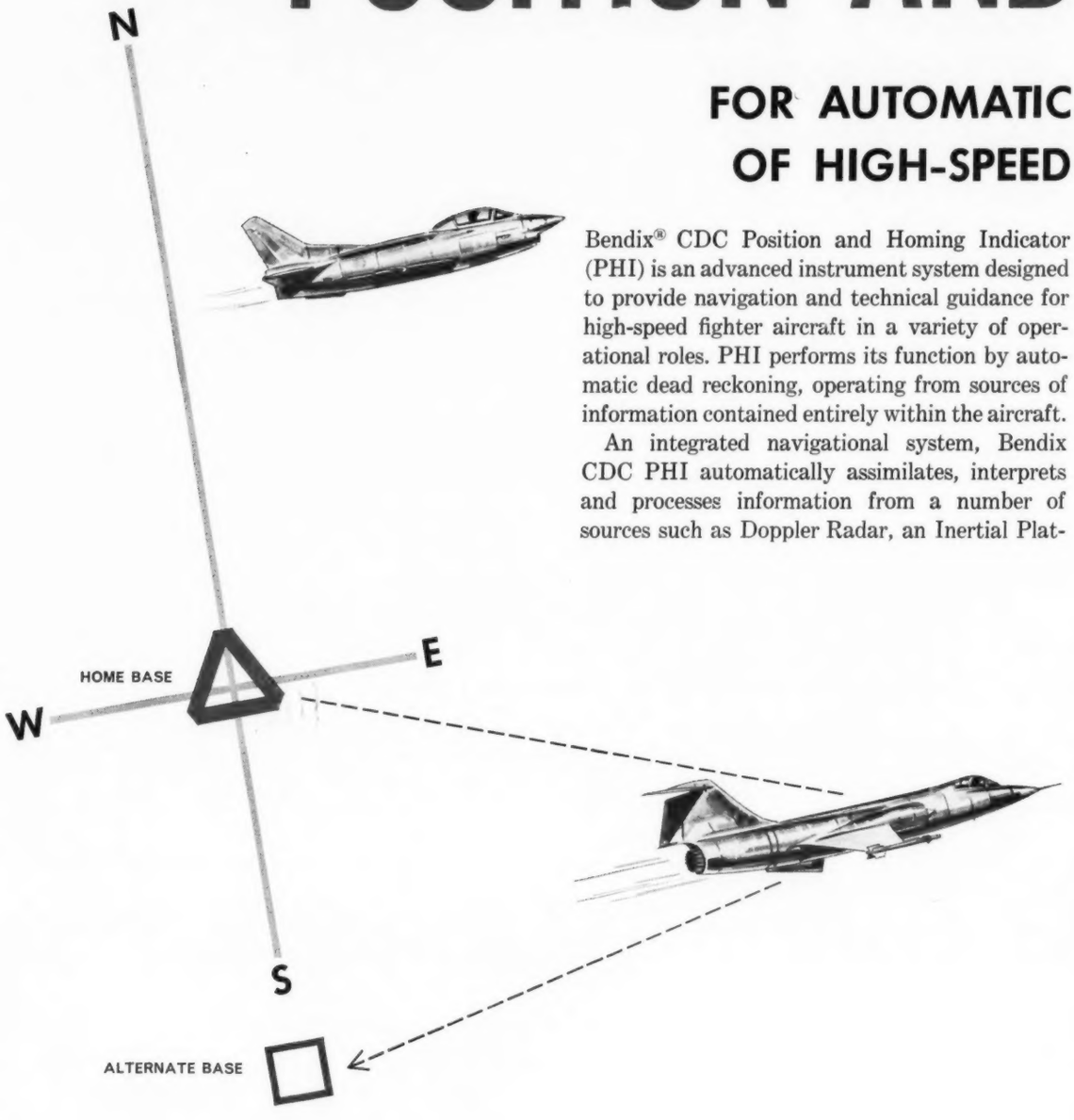

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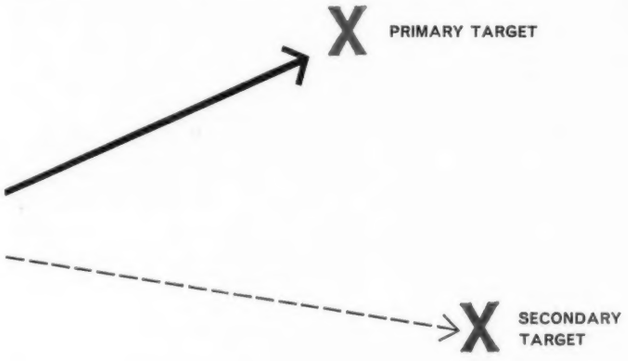

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NASA's Ten-Year Programme

Though up to a little more than two years ago American space research was still primarily an affair of the military, today the main portion of the programme is under the control of a civilian agency, the National Aeronautics and Space Administration.

Awakened by the world-wide echo which followed the radio signals from *Sputnik* and *Lunik*, America's politicians tried, by a strict co-ordination of space research, to make good in a few months for what they had failed to do over the preceding years. One by one, first the Navy, then the Air Force and finally the Army saw a large proportion of their space scientists and research installations withdrawn from their control and handed over to NASA. When first set up on October 1st, 1958, on the basis of the former National Advisory Committee for Aeronautics, NASA had a staff of roughly 8,000. By the time the reorganization is complete in July 1961, its payroll will have reached the figure of nearly 19,000.

In future NASA is to be responsible for all research projects directly concerned with space travel, with the exception of purely military projects, which will continue to be shared among the three armed services. The Air Force is working on military booster rockets and developing the *Midas* early warning satellites and the *Samos* reconnaissance satellites; the Navy is responsible for the *Transit* navigation satellites, while the Army is engaged on development of *Courier* active communications satellites.

It is, of course, impossible to make a clean separation between military and civil projects. For example, the *Transit*, now being developed by the military, will one day be of service to merchant shipping; and conversely the Department of Defense is showing lively interest in many a civil project.

Although NASA has been entrusted with the task of directing space research, is does not carry out anything like all the development work itself. In fact, some 75 percent of the $12,000 to $15,000 million envisaged for NASA during the next ten years will flow into the tills of private industry, which will be given ample opportunity to compete for research, development and manufacturing contracts.

To provide a working basis for further detailed planning and at the same time give industry guiding lines for independent research, a ten-year programme has been drawn up. The objectives, in the words of Hugh L. Dryden, NASA's Deputy Administrator, are as follows:

- "To produce scientific data on the space environment, the sun, earth, and planets, and the galaxy, using unmanned spacecraft equipped with instrumentation and telemetry to relay data to the ground.
- "To study early applications of earth satellites to meteorological research and weather forecasting, long-distance wide-band radio communication, navigation, and similar tasks.
- "To explore the problems connected with the travel of man in space."

To make sure that this ambitious programme can be completed within the coming decade, the amount of new hardware to be developed has been closely limited. This applies most particularly to the booster vehicles, development of which is not only extremely costly but also relatively time-consuming. Whereas it will doubtless be necessary to design a separate payload capsule for each research task, detailed studies of the propulsion problems have shown that half a dozen types of booster vehicle will suffice. It is therefore planned that from 1963 onwards efforts will be restricted to the *Scout, Thor-Agena B, Atlas, Atlas-Agena B, Centaur* and *Saturn*, which are already in a more or less advanced development stage.

Scout is a four-stage solid-propellant rocket capable of lifting a 150-lb payload to a 300-mile earth orbit, and will also be used as an altitude probe. In the next thrust class, the military *Thor-Agena B* is scheduled to replace today's *Thor-Able, Delta* and *Juno II* and to carry geophysical and meteorological satellites into orbit. The *Atlas* is used in *Project Mercury*, but would not be suitable for higher orbits. Designed originally as a booster vehicle for *Midas* and *Samos*, the *Atlas-Agena B* will also be used for civilian purposes, though it will later be replaced by the *Centaur*. The latter, for the development of which NASA is responsible, consists of an *Atlas* as first stage and a second stage using the high-energy propellants liquid hydrogen and liquid oxygen. A detailed account of the *Saturn* is given in the preceding article. Finally, *Nova* with a first stage thrust of 9,000,000 lb, represents the highest thrust class envisaged. *Nova* could lift a payload of 290,000 lb into a 300-mile earth orbit or carry a manned capsule for a soft landing on the moon with subsequent return to earth.

Designations and objects of the projected space vehicles are given in the diagram on page 1368, which can be supplemented by the following brief timetable (booster vehicles are shown in brackets).

1961: First launching of the *Thor-Agena B, Atlas-Agena B* and *Centaur;* First circuit of the earth by a manned *Mercury* capsule *(Atlas);*
First launching of the *Nimbus* weather satellite with constant attitude in relation to the earth *(Thor-Agena B).*

1962: First launching of a three-stage *Saturn* with dummy third stage;
Ranger moon probe for softened impact *(Atlas-Agena B);*
Mariner instrumentation capsule to the vicinity of Venus or Mars *(Centaur).*

1963: First launching of a three-stage *Saturn* with all stages ignited;
OGO earth satellite(s) for geophysical measurements *(Atlas-Agena B);*

Organization of the National Aeronautics and Space Administration. Figures denote number of staff.

1963: OAO earth satellite for astronomical observations *(Atlas-Agena B);*
Group of 12 *Rebound* passive communications satellites *(Atlas-Agena B);*
Surveyor moon probe for soft landing and stationary measurements *(Centaur).*

1964: First production model of the *Saturn;*
Aeros 24-hour orbit satellite *(Centaur);*
Instrumentation capsule around the moon and return to earth *(Centaur);*
Venus or Mars probe.

1965: First flight testing of a nuclear rocket for upper stages (possibly *Saturn).*

1966: Three-man *Apollo* capsule in earth orbit *(Saturn);*
Prospector lunar probe for soft landing and movements on the moon's surface *(Saturn);*
Voyager probe to Venus or Mars *(Saturn).*

1967: First launching of the giant *Nova* vehicle (?);
Circuit of the moon by a manned capsule, probably *Apollo (Saturn?).*

1968–70: Landing of a man on the moon *(Nova?).* ←→

Fair to Cloudy...

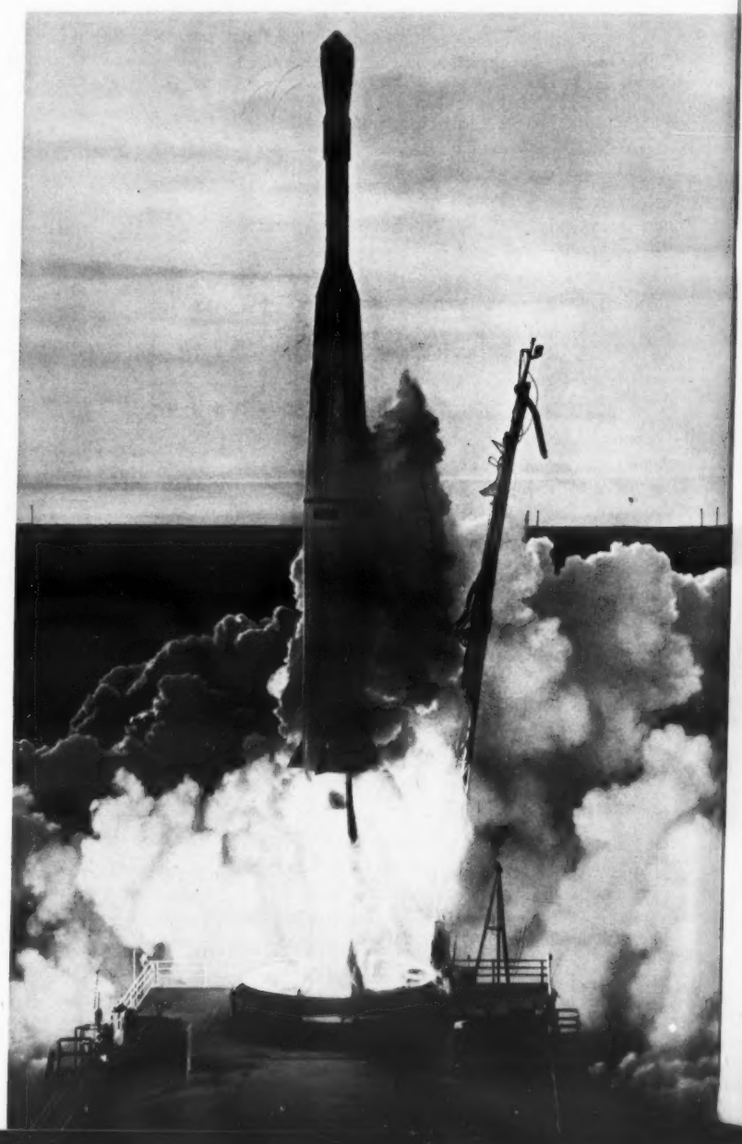
Earth Satellites in the Service of Meteorology

The profession of meteorologist must without a doubt be among the most thankless of our days. For it is his task to forecast one of the most complicated physical processes known to man: the weather. Not only have atmospheric phenomena so far eluded all our attempts to influence them; they also depend on ever-changing factors, many of which are only approximately predictable: air pressure, temperature, humidity, sunshine, etc. Professor Jean Lugeon, Director of the Swiss Central Meteorological Office, has expressed this very aptly: "If these factors were the keys on a piano, one could play on them an infinite variety of tunes which would never resemble one another. Thus the elements of our atmosphere combine every hour to create a new symphony."[1] This being so, it is all the more remarkable that 80 percent of short-term weather forecasts for one or two days in advance are correct.

While the public is more interested in the general trends of weather evolution, such as rising or falling temperatures or the state of precipitations, others require meteorological stations to furnish quantitative forecasts, undoubtedly a more complicated task. But experience has shown that here, too, highly satisfactory results can be obtained.

The scientific weather forecast of today is based on the statistics of past experience. The meteorologist does not restrict himself to conditions in a local area, but compiles a weather map from the data received from a number of observation stations. With the aid of one or more of these maps, each of which represents, so to speak, a snapshot of the weather process, the experienced scientifically trained meteorologist can estimate its further evolution with a reasonable degree of certainty. For long-term forecasts covering a period of several days, the experience and memory of one man are inadequate. What a man does not know, however, he can look up. In other words, the meteorologist looks in his files for a "historical" weather map corresponding as closely as possible to the weather situation in which he is interested, and bases his forecasts on the evolution of the weather situation recorded at that time.

Although this procedure is better than nothing, it cannot be satisfactory in the long run, and the scientist must therefore look out for new solutions. Development is at present under way on a procedure which employs a completely new approach and holds out hopes of a final solution to the problem of accurate weather forecasting. The atmospheric processes are the result of an interaction of forces and energies, which affect the air masses and determine their movements and changes in state. It is therefore pertinent to consider the atmosphere as a heat engine in which the working medium and the power consumption unit are one and the same. In this case, we can set up a heat balance and calculate the atmospheric processes with the aid of known equations from fluid dynamics and thermodynamics.



The three-stage *Thor-Able* carrying the *Tiros I* weather satellite was launched from Cape Canaveral in the early morning hours of April 1st, 1960.

[1] Interavia No. 6/1954, p. 364

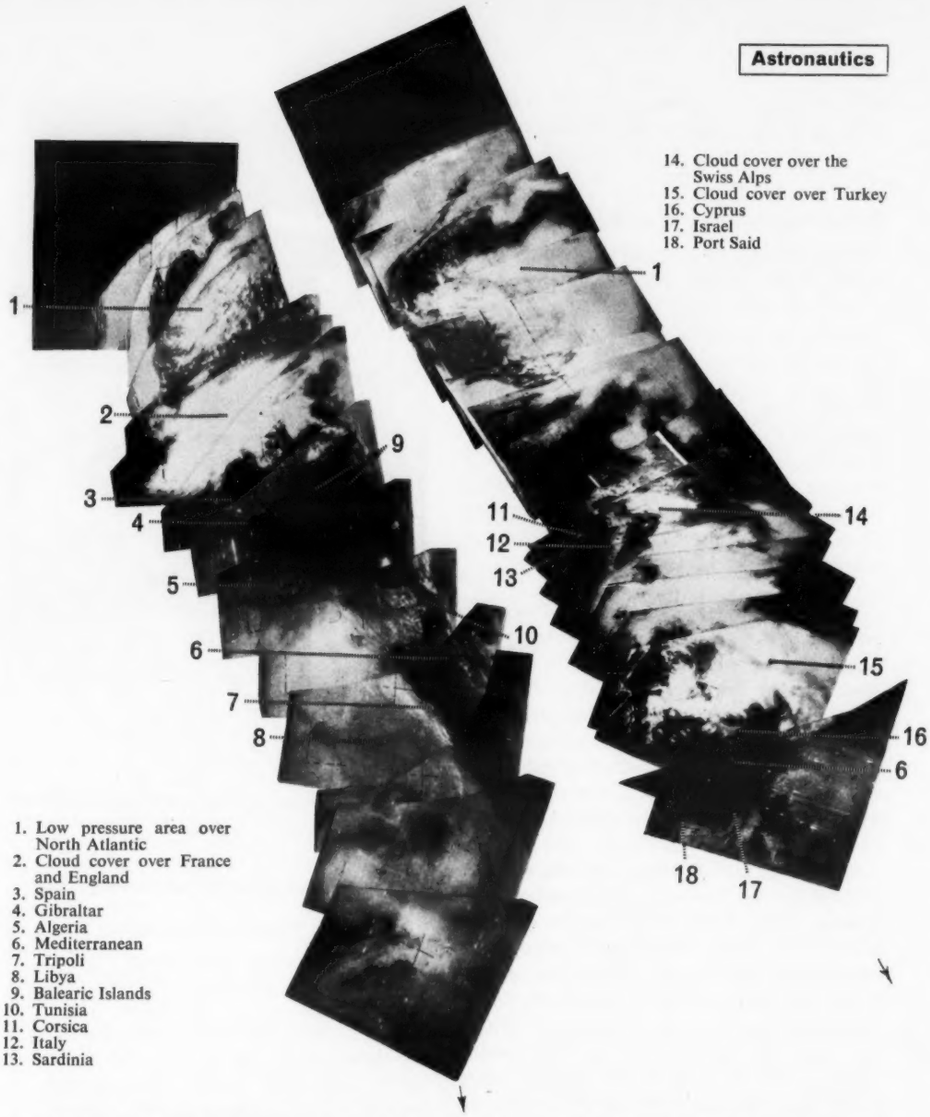
Theoretically, there is no objection to this. Its practical application, however, is faced by a seemingly impenetrable barrage of difficulties.

Let us begin with the energy equation. It must take account of the following forms of energy: sunlight, kinetic energy of air masses, stored heat, radiation of heat into space, condensation heat in fog droplets, sublimation heat from snow or hail, the heat conducted from the atmosphere to the earth and absorbed by the latter, friction heat, and finally electrical energy. And as if all this were not already complicated enough, each of these terms depends on the others and on a series of further factors. The heat radiated by the sun into the atmosphere, for instance, not only varies with season and time of day, but also depends largely on the presence of absorbent and reflecting surfaces (snow, cloud cover, etc.).

Similar difficulties arise in fluid flow equations. Even in the case of air flow around an aircraft wing—a relatively simple, mathematically definable body—theory often breaks down (as in the case of high angles of attack), and the aerodynamicist must resort to systematic experimentation. How much less favourable must seem the prospects of calculating the air flow in the atmosphere—which depends largely on imponderable influences—as it passes over the irregular surface of the earth.

Fortunately, certain simplifications can be made. As any weather map will show, the innumerable local processes are less important than large-scale movement in defining a given meteorological evolution.

If the "analytical" method just mentioned should really be capable of extension—and meteorologists are working at high pressure in this direction—it will suffice to consider large air masses as units and apply the corresponding equations to them.



From the North Atlantic to Asia Minor . . . the weather situation at a glance: the two series of photographs were taken by *Tiros I* during its 14th and 15th orbits. A vast low pressure area lies over the Atlantic (1), marked by a spiral cloud structure. Unbroken cloud cover over France and England (2) and over Switzerland (14) and Turkey (15) appear as white patches, while the Mediterranean (6) looks almost black.

Patchy information

The difficulties of meteorological research have so far lain on the purely practical side, and the assessment of the weather situation has left a certain amount to be desired. Although, in general, the instruments at a ground station uninterruptedly record data such as temperature, pressure, humidity, direction of wind etc., they do so only at one spot. Admittedly, the observation of cloud structure supplies further points of reference, and radio sondes give a picture of conditions at various altitudes. The fact remains, however, that all weather maps indicate the true situation merely at a given number of points, namely at the positions of the meteorological stations, and that only with an approximate degree of accuracy. The full significance of this circumstance will be appreciated when it is known that only one fifth of the earth's surface has an adequate network of observation stations for the plotting of reliable weather maps. The remaining four fifths are more or less unexplored regions, so to speak "blank patches" on the meteorological map of the world. Even between stations lying close together any information supplied can be only approximate, so that all weather maps bear the inherent stigma of inaccuracy.

But for a long-term weather forecast a knowledge of the weather situation in at least one hemisphere, if not over the entire face of the earth, is an essential requirement. If a forecast for one to three hours can be deduced from the evolution trends at one spot, weather conditions in an area with a radius of hundreds, or even thousands of miles must be known in order to make a ten- or twelve-hour forecast. For example, a 12 to 24 hour forecast for Geneva would have to take account of the weather situation in Europa, North Africa, the North Atlantic and the Arctic. In the light of the most recent research, however, long-term forecasts can be made more reliable only if information is available on a global scale.

Space provides the solution

It was left to modern rocket techniques to show the way out of this dilemma and, in the fullest sense of the word, to open up new horizons for meteorological research. The instruments carried by earth satellites can "look down" on the atmosphere from great heights, taking in an area of nearly 400,000 square miles at a glance. On the other hand, the tasks of a satellite moving outside the "interesting"[2] part of the earth's atmosphere must be limited to observations and measurements which can be transmitted over long distances with the aid of electromagnetic waves. Local air pressure measurements will still be the province of the ground stations, at least in the foreseeable future. Of the whole electro-

[2] The portion of the atmosphere which is of decisive importance to the evolution of weather extends from the earth's surface to a height of about 40 miles.

magnetic spectrum, the range of visible light has been the first to become available for telemetry.

Surprisingly regular cloud patterns

Even the first pictures taken from ballistic rockets indicated that the structure of cloud formations was far more regular than had originally been assumed, and it is understandable that the Americans put equipment to photograph cloud cover aboard their first meteorological satellite, *Tiros I*, placed in orbit on April 1st this year. *Tiros* stands for "Television and Infra-Red Observation Satellite," a definition which, strictly speaking, the satellite does not merit, as its infra-red sensors are not designed for photography. *Tiros's* task was merely to supply as large as possible a number of clear cloud pictures.

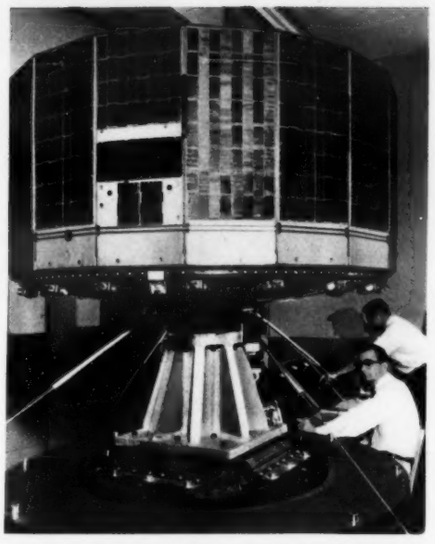
It is possible to take cloud pictures from earth satellites because clouds normally reflect visible light far more powerfully than the earth's surface. Areas of water, for instance, at times reflect only 3 percent of the light falling on them; clouds reflect 10 to 85 percent, depending on structure and density. Fresh snow will, however, reflect up to 80 percent of the light falling on it, so that a clear distinction cannot always be made.

Surprisingly enough, the pictures radioed back to earth by *Tiros* show that cloud systems over a wide area have a very definite pattern. Although it had been discovered from earlier radar observations that tropical cyclones are characterized by spiral-shaped bands of cloud, *Tiros's* wide-angle pictures clearly showed that large cyclones outside the tropics also have this spiral structure. Cloud spirals with diameters of up to 1,500 miles were discovered over the Atlantic, the Pacific and the Indian Ocean.

The discovery of this high degree of organization in the atmosphere confirms meteorologists in their conviction that they are working along the right lines in developing numerical forecasting methods. While a large number of ground stations are available for the observation of the relatively irregular weather processes over land, the movements of air masses over the open sea, which are difficult to follow from the ground, can be detected by satellites in their entirety. Even "primitive" cloud monitors like *Tiros I* can perform valuable services, particularly in the storm warning role. At present, cyclones in remote and little frequented parts of the oceans are brought to the meteorologist's notice days after they begin to develop, mostly through a chance report from a ship or aircraft.

Although even the earliest cloud pictures have made it possible to recognize unsuspected meteorological processes, more richly instrumented satellites will give a more penetrating insight into the complicated mechanism of the atmosphere.

Tiros II, which is scheduled for launching this year, will have, in addition to its television camera, infra-red sensors to monitor thermal processes, and equipment for measuring the intensity of radiation in selected spectral ranges.



Tiros I undergoes a vibration test before launch. The outer casing and top plate (not visible here) are covered with 9,300 photo-electric cells, which can supply up to 50 watts of electrical energy.

Infra-red sensors to probe heat distribution

As already mentioned, the long-term forecasting process under development is based on the energy or heat balance in the atmosphere. Although observations using visible light give a good picture of horizontal flow processes, since the bands of cloud more or less follow the lines of air flow, only infra-red measurements can furnish essential information on thermal processes. The energy radiated by a body depends on its temperature and emissivity. As a rough approximation, many clouds and the earth's surface can be considered as "black bodies" (emissivity one), so that an infra-red photograph would be simply a picture of the distribution of temperature in the area photographed. If the clouds were always colder than the earth's surface beneath them infra-red cameras could take similar pictures by night to those taken by *Tiros I* in daylight.

The conditions just mentioned generally apply in the tropics. In polar regions, on the other hand, clouds often have a higher temperature than the ice beneath them, and in many cases there is no difference at all between cloud temperatures and those in the earth's surface. This difficulty might, perhaps, be overcome through the use of selective receivers which would respond only to those infra-red waves radiated from the earth's surface but absorbed by the clouds. A photograph taken at night would thus show the clouds dark against the light, "visible" surface of the earth, though the problem of distinguishing snow-covered land from clouds of the same temperature would remain unsolved.

It is therefore obvious that many a tough nut will have to be cracked before the highly promising numerical forecasting system can be put into operation.

Isolated clouds throw a hard shadow on the earth's surface. Cloud height can be determined by measuring the width of the shadow.

The "first" meteorological satellite system

There nevertheless exists an interim solution in the form of a procedure proposed at the last IAF Congress in Stockholm, which could substantially improve current forecasting methods by the use of earth satellites.[3]

With this procedure, known as the "first meteorological satellite system," two constantly "downward-looking" satellites would circle the earth on two polar orbits at right angles to each other at altitudes between 2,000 and 4,000 miles, continuously photographing the regions covered. As even "small" cyclonic storms extend over several hundred miles, a resolution of one to five miles would be adequate.

As the trajectories would intersect over the poles, only one ground station would be necessary to receive the data collected by the satellites.

This "world meteorological station" would have to be at a high latitude, for example in northern Scandinavia or Alaska. Forecasts would be worked out at the station and broadcast all over the world by radio; they could even be radioed back to the satellite, stored and finally retransmitted to earth, doing away with the need for a ground network of transmission stations. Forecasts would then, as before, be made by existing analogical methods, i. e., on the basis of similar historical weather processes, supported, however, by far more comprehensive information than that which ground stations are at present able to supply. Owing to the enormous number of individual data which go to make every photograph of an extensive area, a complicated com-

[3] *The Meteorological Satellite*, by R.P. Haviland, General Electric Co., Schenectady, N.Y.

Tiros I weather satellite

The successful launching of the 270-lb *Tiros I* earth satellite on April 1st, 1960 introduced a new era in meteorology.

Within its "active" life of less than three months *Tiros I* transmitted a total of 22,952 cloud photographs, including 17,137 wide-angle pictures which revealed a number of hitherto unknown meteorological processes. The complete evaluation of this photographic material will take years.

Thanks to the reliable functioning of its guidance system, *Tiros I* came very close to reaching the desired trajectory. The planned inclination was missed by only 0.04 degrees. Characteristics of the orbit were: inclination (to the equator) 48.33 degrees, apogee 469 miles, perigee 428 miles, orbital period 99.2 minutes.

Tiros I carried in its base two television cameras, one of them a wide-angle camera to cover an area of 650,000 square miles, and the other a camera with longer focal length for detail pictures. Each had a magnetic tape recorder which stored up to 32 pictures. The storage system was required because there were only two ground stations—Fort Monmouth, New Jersey and Kaena Point, Hawaii —available for reception of the pictures. Direct connections with the satellite were thus restricted to short periods at long intervals.

Thanks to a sequencing system operated by radio commands, the cameras could also be used when the satellite was outside the "hearing" range of a receiving station. At these times, however, it was not possible to take individual pictures at arbitrary intervals, but only series of pictures. On the other hand, during the short periods of radio communication between the satellite and the earth, isolated photographs could be "commanded" from the ground, then being transmitted direct without passing through the storage system. Two frequency-modulated transmitters (200 Mc/s band), each of two watts power, were used.

Being spin-stabilized, *Tiros I* constantly changed its attitude in relation to the earth. The cameras were installed in such a way that their optical axes were parallel to the satellite's axis of rotation. With the aid of calculated or measured data on the position of the satellite at the time of a photograph, each area photographed could be accurately identified, provided the location in space of the satellite's axis of rotation remained unchanged. However, this position changed gradually, owing to outside influences such as radiation pressure, magnetic moments and variations in the field of gravity. Thus in order to ensure that the transmitted pictures could still be accurately located geographically, i.e., that the momentary position of the optical axis could be reconstructed, the circumference of *Tiros I* carried infra-red sensors which produced a pulse when heat radiated from the earth reached them. The length of the pulses and the intervals between them enabled rotation speed and position of the satellite's axis to be accurately determined.

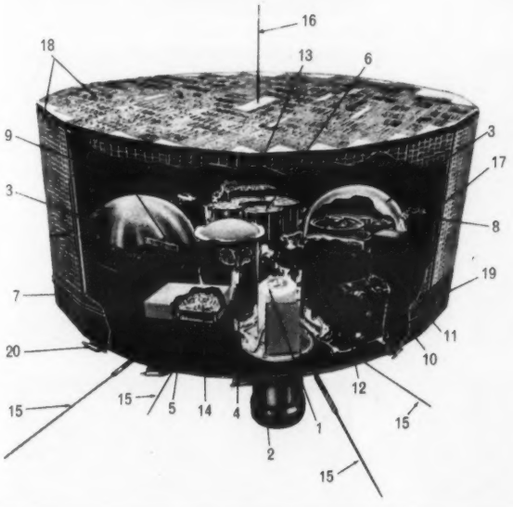
This system successfully located the centre of the area photographed, but not the angle from which the picture had been taken, as the camera continually rotated about the satellite axis. To overcome this difficulty, nine photo-electric cells were fitted round the circumference of *Tiros,* on each of which the sunlight fell for a moment during each rotation of this satellite. Each cell emitted a characteristic pulse, which was transmitted to earth along with the pictures. The computer in the ground station then ascertained the north direction in each picture.

The energy to operate the satellite systems was provided by 9,300 silicon cells on the casing. With the satellite in optimum position in relation to the sun they supplied roughly 50 watts of current. Nickel-cadmium elements served as batteries.

Each camera system with its storage and transmission equipment could work entirely independently of the other. This proved a blessing only ten days after the launching, when the storage equipment for the narrow-angle camera ceased operating. Surprisingly enough, it resumed working a few weeks later.

At the end of June the wide-angle camera system broke down. Although the second camera still appeared to be operational, no further picture transmissions were made. Without the aid of the wide-angle camera and without attitude information—the relevant sensors had also failed—there seemed little prospect of accurately fixing the geographical situation of the areas photographed.

Though originally sponsored by the Pentagon's Advanced Research Projects Agency, *Tiros I* was taken over by NASA in April 1959. The actual satellite was developed by Radio Corporation of America in close cooperation with the Army Signal Research and Development Laboratory, while the U.S. Weather Bureau is responsible for the meteorological part of the programme and for the evaluation of the cloud photographs. ⟷



Sectioned drawing of the TIROS I.-1. One of the two half-inch Vidicon television cameras; 2. wide-angle camera lens; 3. tape recorders; 4. electronic timer for operational sequencing; 5. television transmitter; 6. chemical batteries; 7. camera electronics; 8. tape recorder electronics; 9. control circuits; 10. auxiliary controls; 11. power converter for tape motor; 12. voltage regulator; 13. battery charging regulator; 14. auxiliary synchronizing generator for television; 15. transmitting antennas; 16. receiving antenna; 17. solar sensor to measure position of satellite with respect to sun; 18. solar cells; 19. despin mechanism; 20. spin-up rocket.

parative and selective process is necessary. The method normally used in classifying fingerprints could serve as a model for such a procedure.

The "second" meteorological satellite system

As scientific knowledge progresses, it will finally become possible to pass on to the "numerical" forecasting system mentioned earlier: here the indispensable requirements will be a thorough knowledge of the mechanics of the atmosphere and the measurement of different forms and movements of energy. The measurement of solar energy reaching the earth and energy radiated or reflected from the earth into space should not present insuperable difficulties, and here a scanning technique for measuring local values would be preferable to the measurement of an average value over a wide area, as it would also take account of limited local phenomena. In addition, the kinetic energy of air masses could be determined indirectly, for instance by filming cloud movements.

For the measurement of water vapour content in the atmosphere, spectral analysis is available, particularly at radar and infra-red frequencies. Here use is made of the fact that water vapour, like any other gas, absorbs certain wavelengths. To avoid falsification of the measurements by other types of absorption, they could be carried out on two neighbouring frequency bands, only one of which is absorbed by water vapour. Knowledge of the height of a cloud base would also provide information on the moisture content of the atmosphere. It appears possible to determine the heights of clouds above the earth's surface with the aid of earth satellites when the clouds cast a clearly visible shadow. When the angle of incidence of the sun's rays is known, cloud height can be calculated by a simple formula from the length of the shadow and the angle from which the photograph is taken. But this requires the television camera to have an exceptionally high resolution, as the areas to be measured can, on occasion, be well under a hundred yards.

A direct measurement of surface air pressure from satellites would appear impossible, although under certain circumstances the flow equation method might have some chances of success. Such equations provide a relationship between pressure, density and speed of the fluid medium. A means of measuring speed has been mentioned above. Determining the density of the atmosphere seems possible with the use of the absorption spectrum, this time not for water vapour but for oxygen or nitrogen.

Finally, storms or other electrical phenomena in the atmosphere can be detected by measuring their radio noise.

*

It is true that the way to 100 percent reliable weather forecasting is long and hard. But even the relatively modest success of *Tiros I* holds out hopes that within a few years satellite techniques will benefit the man in the street. ⟷

"Cyclone-Prints" from Satellite (Tiros I)

By Sigmund Fritz, U.S. Weather Bureau, Washington, D.C.

Tiros I was launched on April 1st, 1960 and obtained cloud pictures of excellent quality with both its narrow-angle and wide-angle cameras. In every instantaneous exposure, each of the wide-angle cloud pictures revealed phenomena covering thousands of miles, in resplendent detail. Although *Tiros I* did not yield the sought-after, daily, world-wide coverage, it photographed many kinds of terrain and climes, stretching from about latitudes 55° N to 55° S. It saw and reported cloud systems in the tropics and in mid-latitudes; it saw ice in Canada and the hot land in Africa; it televised oceanic and desert regions, and mountainous and coastal areas. The photographed cloud patterns ranged in size from the large-scale vortex to the mesoscale local severe storm and the small-scale cumulus cloud.

The clouds revealed by *Tiros* were produced by physical processes in the atmosphere. In general, moist air in the presence of adequate upward vertical motions will result in cloud formations. But whether large-scale cloudiness or clouds of a more local nature are formed, or whether stratiform or cumuliform clouds are produced, depends on several factors including the three-dimensional temperature, moisture, and wind structures of the atmosphere. Thus it should be possible to examine the photographs and cull from them significant meteorological information about the state of the atmosphere which was associated with the particular cloud patterns under study. Moreover, in some special cases the cloud systems seen in the pictures resemble phenomena which have been studied in theoretical and laboratory investigations; in those cases it will be valuable to compare the state of the atmosphere which produced the clouds in the pictures with the theory and with the laboratory results. Where the results found from *Tiros* do not

Fig. 1

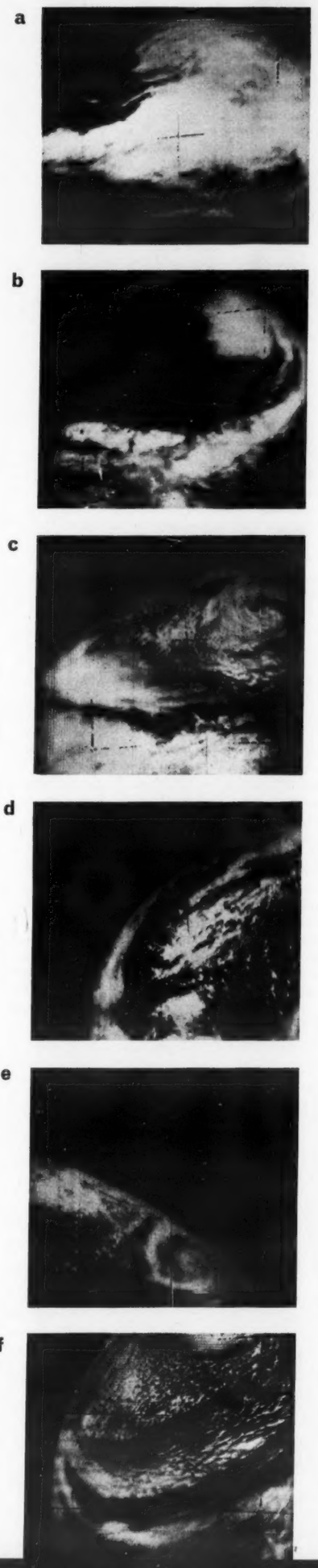
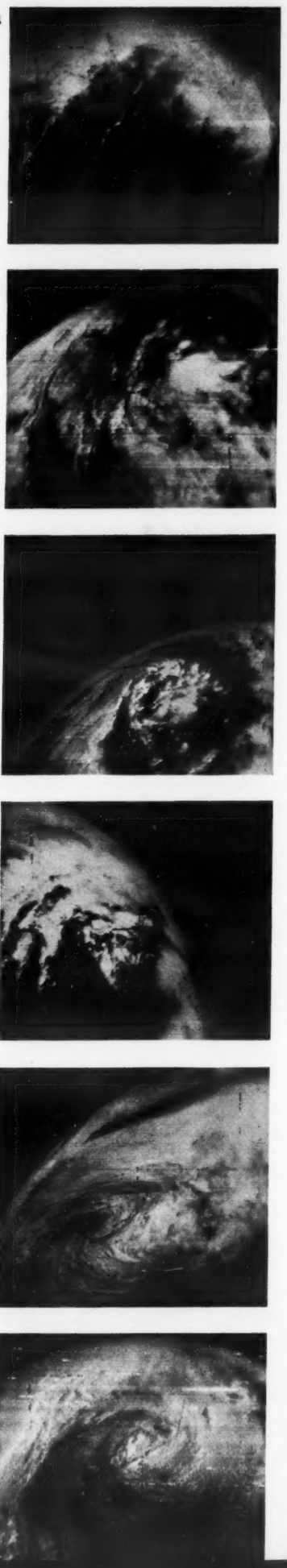


Fig. 2



Figs. 1 and 2: Typical cloud systems over the northern (left) and southern (right) hemispheres. All pictures were taken by the *Tiros I* weather satellite.

agree with previous investigations, further research into the basic fluid mechanics will be needed before the atmospheric processes which produced the clouds can be adequately understood. Thus *Tiros I* is leading the way to basic investigation of the atmosphere from space platforms.

Among the most striking cloud patterns seen in *Tiros* pictures are the large-scale cyclonic *vortices*—vortices whose spiral bands sometimes reach over a thousand miles in diameter. The vortices often have common characteristics; yet they are all different. It's as though each cyclone which spawned the cloud vortex has its own "cyclone-print," just as each person has his own "finger-print"; in both types of prints there are similarities—yet each print has its own identifying characteristics. A collection of such "cyclone-prints" is shown in *figs. 1* and *2*. *Fig. 1* contains examples of Northern Hemisphere vortices, while *fig. 2* shows some in the Southern Hemisphere.

The presence of moist or dry air, the relation of spiral and other bands to the wind flow and to the "jet stream," the existence of weak or strong frontal zones—these and other meteorological phenomena can be inferred from the cloud pictures. For example, *fig. 1b* represents the clouds associated with an occluding cyclonic system in the middle of the United States; a marked frontal cloud separates the cloudless, cold air (dark area in center) from the warmer moist air to the right. *Fig. 1d* is one frame from a series of pictures taken over an old storm in the Atlantic ocean. A part of the stratiform cloud which surrounded the entire storm can be seen at the left and in the lower right corner. This stratiform cloud was coincident with a stream of warm moist air; but the central part of the storm, associated with the less uniform cloud mass in the centre of *fig. 1d*, contained a deep mass of cold dry air. When warm and dry air lie side by side with the winds flowing cyclonically around the cold air, it is known that the wind will increase with height near the boundary between the warm and cold air. Thus a region of relatively high winds, sometimes resulting in a "jet stream," can usually be found in such areas. And in the case of the storm associated with *fig. 1d*, it was indeed found that a region of high winds, of about 60 knots at 17,500 feet, increased near the inner edge of the stratiform cloud. Similar regions of high winds have also been found near boundaries in *fig. 1c*, and near still other frontal zones. The cloud system in *fig. 2c* is similar in general appearance to the clouds in the Atlantic storm described above. A stratiform cloud practically encircles the storm, while a more broken cloud mass resides in the middle; a relatively cloudless area separates the stratiform cloud from the central cloud area. One might perhaps therefore expect that a warm moist air current surrounds a deep cold mass of air in the centre; and one might in that case also expect a region of relatively high winds near the boundary between the stratiform cloud and the relatively cloudless (dark) area.

Another storm of interest is the typhoon cloud system shown in *fig. 2a*. In this case the existence of a storm north of New Zealand was known; *Tiros* was therefore programmed to televise this storm which turned out to be the first typhoon ever photographed from a satellite.

An interesting discovery in *fig. 1f* is that at least some of the dark bands represented secondary fronts.

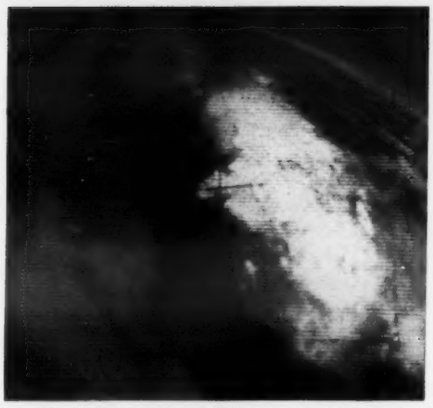


Fig. 3: The Straits of Gibraltar; right, the Mediterranean coast of Spain; left, Morocco; in the rear the Atlantic Ocean. A bank of cloud (white) lies over Portugal.

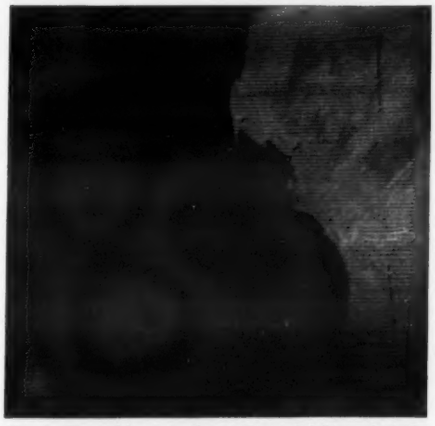
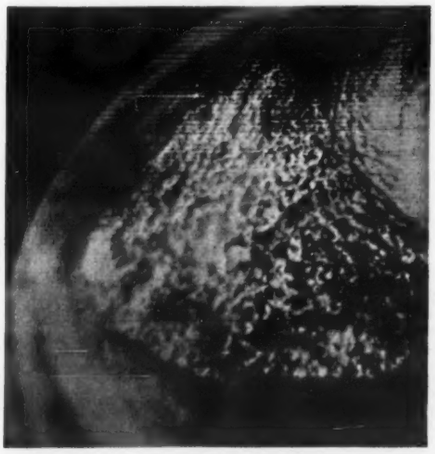


Fig. 4: The African continent shows bright against the dark Atlantic. Picture shows the coast of Mauretania between Cape Blanco and St. Louis.

Many additional phenomena have been found in the *Tiros* pictures. For example, a broad band of clouds between two intense cyclonic systems in the Pacific was photographed and found to resemble classical cyclone models. A widespread cloud configuration *(fig. 5)* covering thousands of square miles which looks very much like the Bénard cells produced in the laboratory, but which doubtless is produced in a much more complicated manner in the atmosphere, was observed on several occasions; the cellular pattern was found to exist in the presence of unstable air up to about 5 to 8 thousand feet, with a marked dry inversion above that height. Cloud streets in the tropics were photographed and were observed to lie within about 30° of the wind direction at 10,000 feet.

Fig. 5: This cloud structure recalls the Bénard cells familiar from laboratory work.



Although some of the most striking features of *Tiros I* are associated with the pattern of clouds over thousands of miles, patterns of much smaller-scale phenomena are also revealed. An example of this is a cloud about 80 miles on a side imbedded in an interesting meteorological configuration of clouds and clear air. This cloud covered a thunderstorm area at the time that the picture was taken, but two hours later hail and tornadoes were produced in the same cloud.

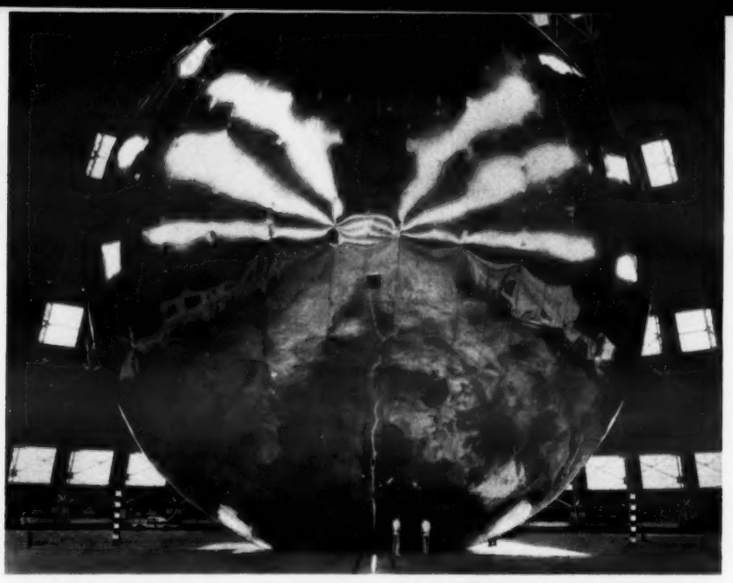
The satellite can show not only cloud formations; for example there are a great many interesting coastlines which can be seen in the pictures; and the difference in the detectability of coastlines produced in part by the contrast between the brightness of the land and the brightness of the ocean is very striking in some cases *(figs. 3 and 4)*. For example, the North African coast is very visible by comparison with the dark Mediterranean Sea. But other land forms such as the Florida Peninsula and the southern part of Africa, both of which have been photographed, appear dark with only slight contrast between land and oceans. When snow is present on mountain peaks, these produce very bright areas; for example, *Tiros* photographed the Alps for several days in succession from about April 2nd to April 6th; and on those days when the Alps were not cloud-covered the deep valleys such as the Rhone River Valley could be clearly seen in the photographs. Snow in *Tiros* photographs of the Himalayas is indicated by the very marked ridge configuration which one sees in the rugged mountain forms.

Sometimes odd looking clouds appear; a long cloud about five miles wide and almost 1,000 miles in length was photographed in the vicinity of the Gulf Stream, and the possibility that it is related to the Gulf Stream is being investigated.

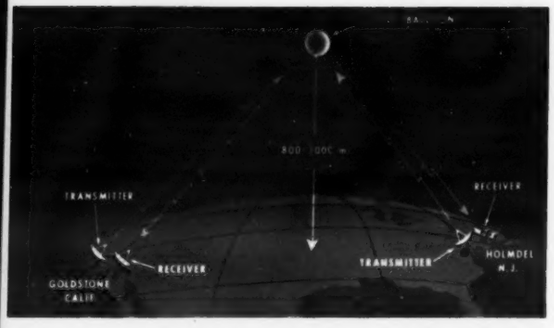
And still other phenomena can be seen in the *Tiros* pictures, many of which raise new questions about the basic processes which occur in the atmosphere. Although the search for basic information about the atmosphere and the earth with the aid of satellites has just begun, we already see ways of applying the cloud information. In order to forecast the weather it is necessary to know the state of the atmosphere at the time the forecast is being prepared. The pictures from *Tiros I* have already been used on a few occasions to supplement conventional observations, in order to determine the position of storm centres and of fronts in Pacific and Atlantic areas. But, in addition to the mere location of systems, methods are being investigated by which the pictures can help improve the "initial" analyses of the vertical motion fields and of the moisture field in the atmosphere; such improved analyses will be valuable in forecasting by dynamical methods, especially in oceanic areas. Of course further progress can be expected as additional knowledge is gained about the atmosphere from satellite cloud pictures and from other satellite experiments already in being *(Explorer VII*—heat budget) or in the process of preparation *(Tiros II, Nimbus* and *Aeros)*. ←←

Astronautics

A Radio Reflector in Space: Echo I



Test filling at the works. A few pounds of gas will keep the balloon rigid in airless space, but about 40,000 lb of air are necessary to inflate *Echo I's* skin on earth.



How a passive communications satellite works. The VHF waves (tone, voice radio, television) radiated by a transmitter pass freely through the ionosphere, are reflected from the metal-coated skin of the balloon satellite and can be picked up by a receiver antenna several thousand miles away.

Above and below: The 150 ft Mylar panels being inspected and folded. These will make up the skin of the *Echo* satellite, which is just over a hundredth of a millimeter thick.

When, on August 12th this year, a radio message from President Eisenhower was beamed into space from California, reflected by the earth satellite *Echo I* before it completed its first orbit and clearly picked up by the antenna of the Holmdel research station nearly 3,000 miles away, a new era of communication techniques began. For this experiment proved beyond all doubt that it is possible to transmit communications in the VHF range over thousands of miles with the aid of so-called passive or reflector satellites.

Since the best shape for an omnidirectional reflector is the sphere, a passive communications satellite can be designed as a non-rigid balloon. *Echo I* circles the earth at a height of roughly 1,000 miles, where an internal pressure of 3 millionths of an atmosphere is enough to keep the balloon inflated. The skin is made of a large number of panels.

It was calculated that the temperature of *Echo I* would drop from +240 °F in the sunlight to −80 °F when the satellite came into the shadow cast by the earth. As there was the risk that the gas inside would resublimate and cause the balloon to deflate, the trajectory was so chosen that *Echo I* remained constantly in sunlight for a few days. Since August 22nd, however, each of the satellite's orbits has brought it into the earth's shadow without affecting its performance as a radio reflector. To ascertain whether there were distortions in the sphere, circularly polarized waves were transmitted; the polarization of the reflected waves showed that the skin had developed only a few wrinkles.

As *Echo I* has been punctured by meteorites, the gas inside is escaping—slowly because of the very low inner pressure, but nevertheless continually—and the satellite will finally lose its spherical form. To delay this process, the 10 lb of benzoic acid, which rapidly vaporized in the sun's rays and inflated the balloon after the satellite was ejected, were supplemented by 20 lb of anthraquinone, a substance which vaporizes slowly owing to its low vapour pressure and which will replace the gas as long as supplies last. In later *Echo* satellites the skin will be stiffened with a substance which becomes rigid after the balloon inflates.

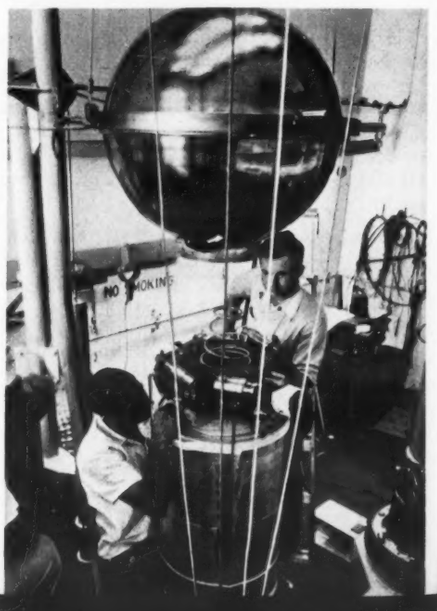
At a distance of over 1,000 miles above the earth, the 100 ft diameter of *Echo I*—so far the largest artificial satellite—covers less than a fifteenth of a second of arc. Despite highly developed amplifier techniques making use of masers (cf. *Interavia*, No. 3/1960, p. 335 et seq.), signal transmission by passive reflector over such long distances is possible only if the transmitting and receiving antennas are directed with a high degree of precision.

For this purpose, however, the orbit must be known accurately in advance. The data obtained from tracking the satellite are passed to an IBM 709 digital computer, which then supplies the coordinates for further orbits. To simplify tracking of *Echo I*, two non-directional transmitters, fitted at opposite points on the skin, were fed by solar batteries. Nickel-cadmium batteries initially stored energy for the periods when the satellite was in shadow, but as these batteries have now ceased to function, tracking in the dark is possible only by radar.

Since one satellite can maintain communications between two stations thousands of miles apart for only a few minutes, the minimum number of satellites necessary for uninterrupted communications between any two points on the earth would be twelve. These twelve satellites would, however, have to be placed in orbit according to an exact schedule; and this is likely to present some problems for the time being. With 25 to 30 satellites circling on "random" orbits it might, however, be possible to maintain uninterrupted world-wide communications, if reliability were adequate.

Although many problems are still awaiting solution, experience with *Echo I* holds out promise that in the near future radio communications will become an economically useful field of application of astronautics. ⟿

The payload is here being mounted on the third stage of the booster. When folded, the satellite will fit into a magnesium sphere with a diameter of 26 inches. Before the container opens, it is ejected by a spiral spring on the third stage (visible in picture). The third stage is set in tumbling motion by small rocket motors and remains behind the unfolding balloon.



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Gas beam from an arc rocket motor of Avco Research and Advanced Development Division. During an endurance test, the motor delivered an average of 340 grammes of thrust, for a specific impulse of 1,000 seconds. Power required was no less than . . . 30 kilowatts.

Electrical Propulsion Systems for Spacecraft

Though its basic theory was barely known a few years ago, and the subject itself was given but scant mention in literature, electrical propulsion for spacecraft is today the object of extensive research and development in the United States—and probably in the Soviet Union.

However varied the different practical forms of electrical propulsion systems may be, they all have two features in common: in the first place the propellant mass is ejected with the aid of electrical energy, and in the second place, unlike chemical rockets, electrical propulsion systems require a separate source of energy. Although the latter, together with its auxiliary equipment and the energy converter, represents additional dead weight, electrical propulsion systems are, thanks to the far greater speed of the propellant masses, superior to chemical rockets for many tasks: for correcting the trajectory and controlling the attitude of earth satellites, ferrying spacecraft from a low orbit to a higher one, transporting cargo to the moon, and interplanetary journeys.

In principle these tasks can also be performed by chemical rockets, but here the limited specific impulse—around 350 seconds for the high-energy propellants liquid hydrogen/liquid oxygen—leads to astronomical figures for launching weight, even for small payloads. The exploration of distant planets cannot even be undertaken until electrical power units are available, since the length of the journey would preclude manned trips with chemical rockets.

Electrical propulsion systems work with specific impulses of 1,000 to 100,000 seconds, but deliver only very small thrusts and hence low accelerations—roughly in the order of a few ten-thousandths of the earth's gravity. They are therefore unsuitable for either the first stages of booster vehicles or retro rockets, such as are required for decelerating a space ship in preparation for a landing on the moon or a planet.

There are three main groups of electrical power units:[1]

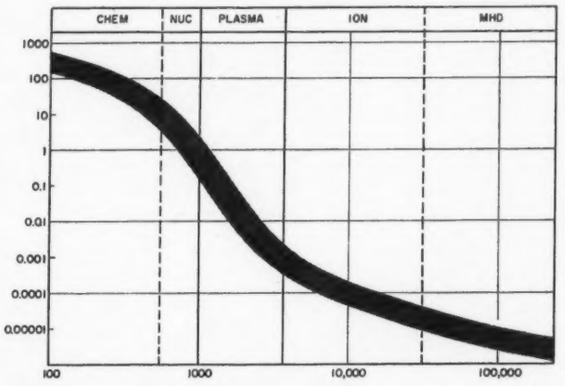
1. electrothermal propulsion (also known as electrothermodynamic propulsion or arc jet systems);
2. electrostatic or ion systems;
3. magnetofluiddynamic systems.

First test run of a plasma motor at Republic Aviation Corporation. The propellant gas is nitrogen. No further details are known.

Electrothermal rockets

Here electrical energy is used to build up a stationary arc between a central and an annular electrode. The arc heats a propellant gas which exhausts through a nozzle at high velocity. In certain respects, this process recalls that of chemical propulsion, except that far higher gas temperatures can be obtained with the aid of the arc than with the energy released by the chemical processes. If the chamber walls are carefully cooled, mean gas temperatures of up to 12,000 degrees Kelvin should be possible—far above the melting temperature of the chamber walls—whereas in the arc itself temperatures of up to 50,000 degrees Kelvin can occur. In laboratory experiments at 3,000 degrees Kelvin and using hydrogen as propellant gas, exhaust velocities of 10 to 11 kilometres per second have been measured, which correspond to a specific impulse of 1,000 to 1,100 seconds. There are hopes that 15 kilometres per second can be achieved within the next 15 years; the top limit probably lies at around 20 to 25 kilometres per second.

Electrothermal rockets are not only remarkable for the simplicity of their structure, but are also highly suitable for thrust control purposes. If the flow mass of propellant gas is increased, with a constant supply of energy, then the gas temperature falls—and hence also the exhaust velocity, while the thrust rises.



"*Impulse spectrum*" *for rocket units*. Specific impulse is entered on a logarithmic scale on the abscissa, the ratio of thrust to total weight of the power unit on the ordinates. CHEM = chemical rocket; NUC = nuclear reactor propulsion; PLASMA = here electrothermal propulsion; ION = ion beam motor; MHD = magnetohydrodynamic propulsion.

Although the experiments so far carried out have produced some very encouraging results, there are still plenty of problems to be solved before the operational stage is reached: stability of the arc, cooling of the electrodes and the chamber walls, erosion of the electrodes . . . to mention only a few.

The National Aeronautics and Space Administration's space research programme calls initially for the development of an arc motor with a power requirement of 1 kilowatt, which could be used for the attitude control of spacecraft in place of the current compressed gas bottles. For propulsion proper a larger unit is projected; this would take its electrical power from the 30-kW SNAP-8 reactor/generator which NASA is developing in conjunction with the Atomic Energy Commission and which is scheduled to begin flight testing in a two-stage *Saturn* in 1965.

Electrostatic systems

The name more and more commonly given to this second group of propulsion systems is ion beam engines or ion rockets. The propellant mass consists of ions, which are accelerated with the aid of electrical fields to velocities of from 10 to 200 kilometres per second. The structure of a typical ion rocket is shown in the accompanying drawing. The exhaust velocity of

[1] The following statements are taken in part from a paper on "Progress in Electric Propulsion Systems," read by Dr. Ernst Stuhlinger at the 11th International Astronautical Congress in Stockholm.

the ions, and thus the specific impulse, grows with the square root of the field voltage and is inversely proportional to the square root of the ratio between particle mass and particle charge. Or in other words: heavy ions require high voltages. The higher the field strength, the greater the thrust obtainable per unit area of the beam cross-section; because of the danger of short circuits, however, the top limit probably lies at around 100,000 volts per centimetre, corresponding to 8 grammes of thrust per square centimetre. The use of the highest possible field strengths also helps to reduce weight, since the engines can then be built in compact and light form. Admittedly, this leads to extremely small distances between electrodes, so that here too there are structural limits. If, for example, it were desired to accelerate caesium ions to an exhaust velocity of 100 kilometres per second, with the above-mentioned highest permissible field strength of 100,000 volts/centimetre, then the distance between the electrodes would have to be no more than 0.07 centimetres, which is virtually unrealizable in practice.

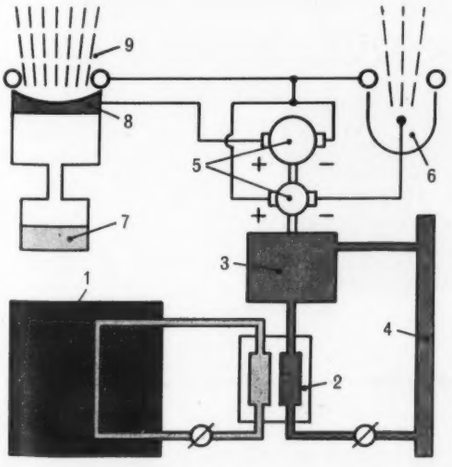
These caesium ions are not only relatively heavy (atomic weight of caesium = 133)—a desirable quality, as will be seen from the above remarks—but also can be easily produced. They are released when caesium vapour is diffused through a thin layer of porous tungsten. If the temperature of the tungsten is around 1,400 degrees Kelvin and if the pores are sufficiently small (1 micron), then more than 99 percent of the caesium vapour is ionized. The high temperature, however, provokes considerable radiation losses.

The problem which causes the technicians the most trouble has its origin outside the actual rocket: namely the neutralization of the beam behind the thrust nozzles. To prevent the spacecraft from becoming statically charged, positive and negative charges must be ejected in equal numbers. In addition, it is essential that these charges should reunite immediately behind the thrust nozzles, as otherwise the ion flow would be "throttled" within a very short time. This presupposes that the positive and negative particles exhaust from the nozzles at equal velocity. But the negative particles will generally consist of electrons, the positive of heavy ions; what is more, caesium ions have 250,000 times the mass of electrons. To give both the same velocity, the voltage at the electrodes of the electron nozzle would have to be in a ratio of 1 to 250,000 to the voltage at the electrodes of the ion nozzle. With such small voltages it is impossible to maintain a uniform electron flow. There is some hope that this difficulty can be overcome by accelerating the electrons at right angles to the direction of the beam, so that inside the beam they perform mainly an oscillating motion, with only a small velocity component in the direction of the beam, a component of the same magnitude as the ion velocity.

In theory, then, there are promising courses of development, but in practice many obstacles must still be overcome. Conditions in the laboratory, especially as regards beam neutralization, are considerably more favourable than in space, so that tests must be made with the aid of high-altitude probes or earth satellites before the situation can become really clear. Tests of this kind are scheduled to begin in 1962.

Magnetofluiddynamic propulsion

The thorny problem of beam neutralization does not arise here, as the propellant masses—though largely ionized—are not separately accelerated according to positive and negative charges, but externally form a neutral plasma. If plasma is brought into an electrical field, particles of opposite signs move in opposite directions. If a magnetic field is then added, with lines of force at right angles to those of the electrical field, the result is a spiral motion of the particles, with the velocity components in the same direction at right angles to the lines of force. In this way it is expected that beam velocities of up to 1,000 kilometres per second can be obtained, corresponding to a specific impulse of 100,000 seconds. Such prospects are obviously attractive; but before practical applications can be envisaged, not only a complete theory of conductive gas flows must be built up, but also a series of



Typical structure of an ion beam motor. Key: 1. fission reactor; 2. heat exchanger; 3. turbine; 4. radiation cooler; 5. d.c. generator; 6. electron generator; 7. propellant; 8. ion generator; 9. ion beam in electrical field.

Careful checking of the Avco arc rocket motor before it is placed in the vacuum chamber.

complicated auxiliary systems, without which plasma motors cannot function, must be developed. These include condensers for high voltages, electromagnetic field coils, components for high-speed switching sequence, etc.

Sources of energy

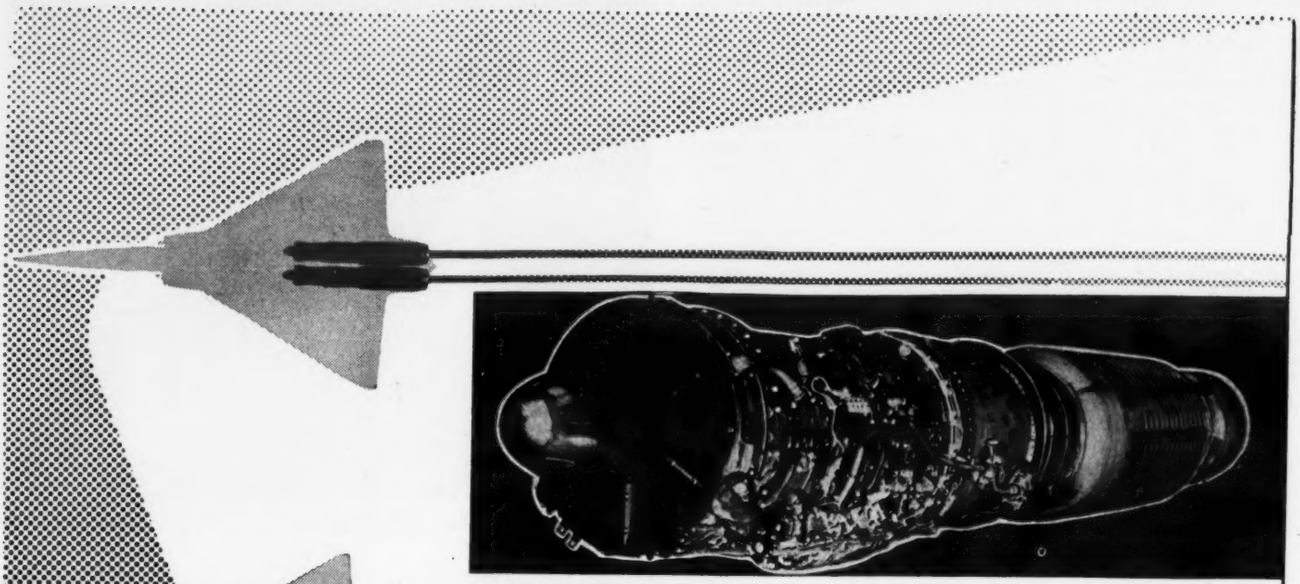
Unless further basic discoveries open up new sources of energy, there are fundamentally only two practical sources of power for electrical propulsion systems: the sun and nuclear reactors. Solar energy is available without cost and in unlimited quantities, and does not need to be carried aboard the spacecraft. These undeniable advantages, however, are balanced by serious disadvantages: the energy flow per unit of area is small—an average of 0.13 Watts per square centimetre on earth—and what is more decreases with the square root of distance from the sun (only 0.055 Watt/cm² on Mars, for example), so that large areas of solar cells would be needed. If the spacecraft enters the shadow of the earth or another planet, the supply of energy ceases completely.

The scientists are therefore concentrating their efforts on the development of efficient nuclear reactors for continuous operation. Here the efficiency of a propulsion system is decisively affected by the output in kilowatts obtainable per kilogramme of structural weight. It has been found that the weight of the reactor and heat exchanger is of minor significance compared with that of the cooling system, the screening and the energy converter. According to the estimates of responsible experts, it should be possible to obtain roughly 0.1 kilowatts per kilogramme of structural weight by 1965, 0.3 kilowatts by 1970 and finally some 10 kilowatts by 1980. The optimum energy conversion system must be chosen in the light of similar considerations. In the present state of the art, turbogenerators appear to be superior to all other systems—thermo-elements, temperature ionization, photo-electric cells (for solar energy)—as regards reliability and efficiency.

The applications

Electrical propulsion systems—presumably ion rockets—will probably have their first practical application in 24-hour satellites, which will render invaluable services as radio relays. A satellite of this kind must first of all be placed accurately in orbit. Secondly, in view of the many unavoidable disturbances, its trajectory must be constantly corrected, to ensure that it does not change its position in relation to the earth. Thanks to their compact construction, their high specific impulse and their controllability, arc or ion rockets will probably be better suited to this purpose than chemical rockets or compressed gas nozzles. Moreover, a communications satellite in any case requires large quantities of electric power.

Although up to a certain distance limit, electrically-powered vehicles would take longer to complete the journey than a chemical rocket, beyond this limit there is a growing time advantage in favour of the electrical system. An unmanned space freighter for a short journey could, for example, use electrical propulsion to advantage, since this would enable it to carry a considerably higher payload for the same total weight, and the longer journey time would not be a major handicap. For journeys to Mars or Venus the electrical power unit would not bring any time saving, but it would again permit a better relationship between payload and total weight than the chemical rocket. Finally, for really long trips in interplanetary space the electrical propulsion system will become indispensable, because of the time factor. Whereas a chemically-powered space probe would take more than 40 years to reach Pluto for instance, this same journey could be completed in only three to four years with an electrical propulsion system. ◆◆



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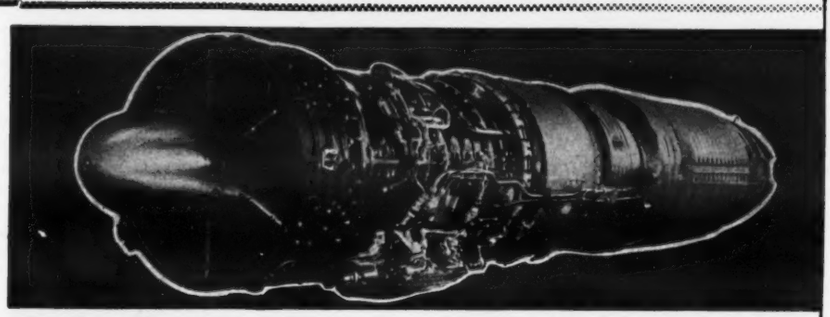

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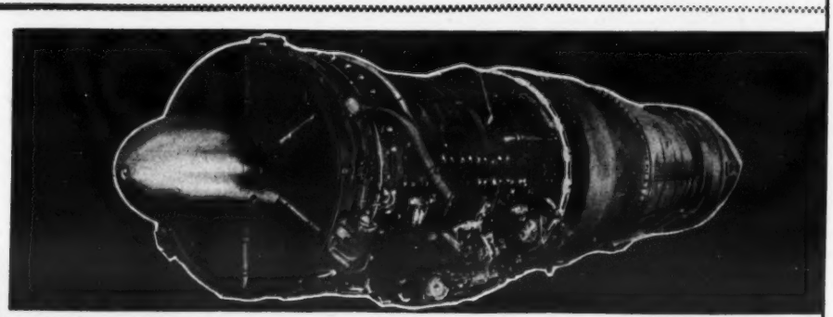

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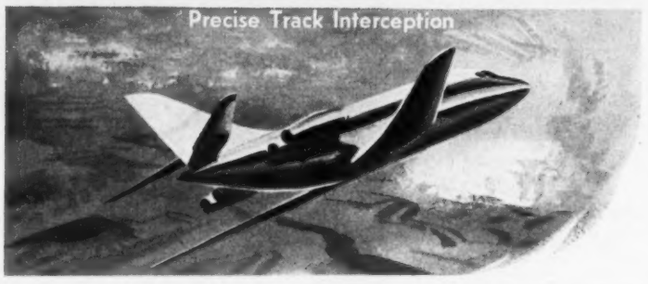

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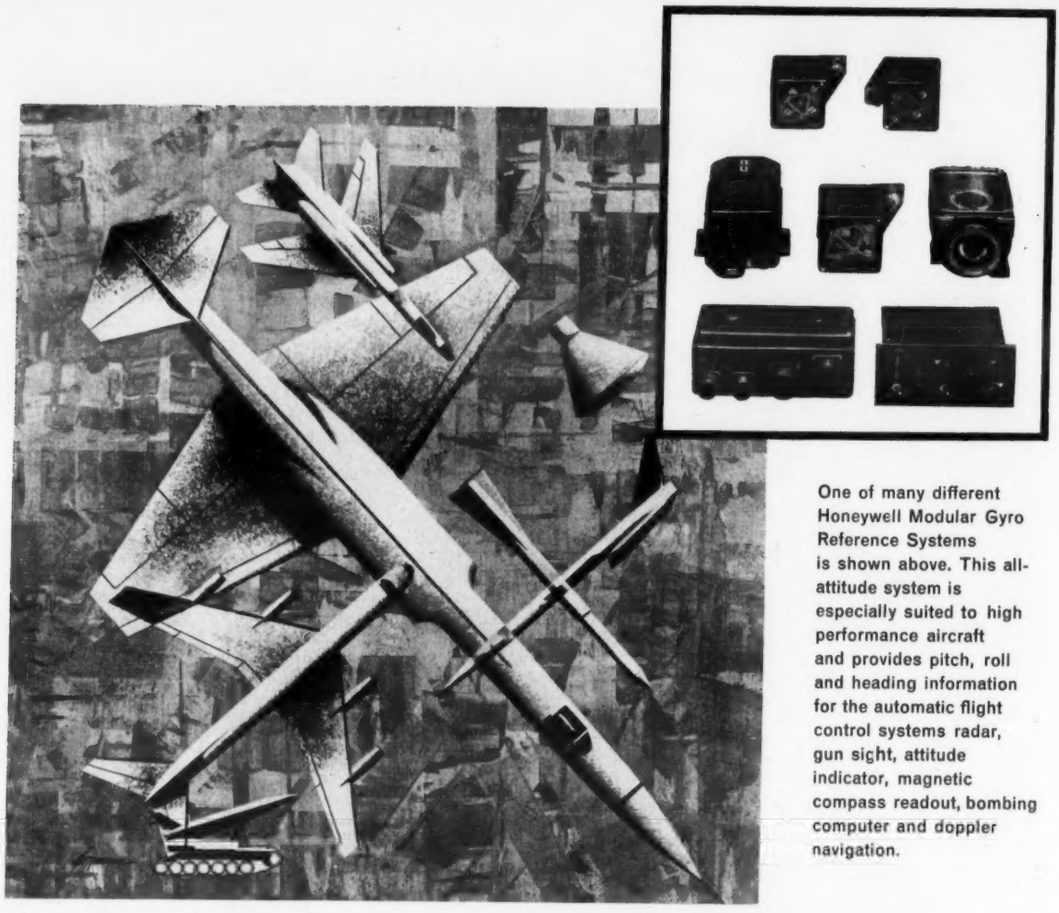

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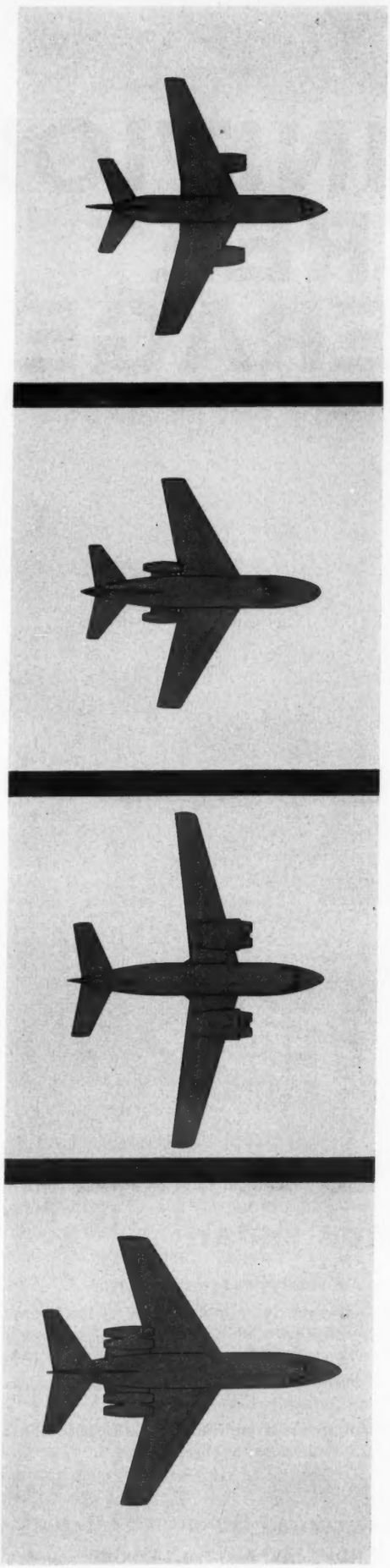

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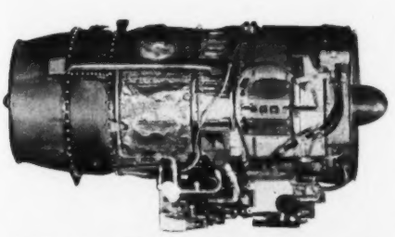

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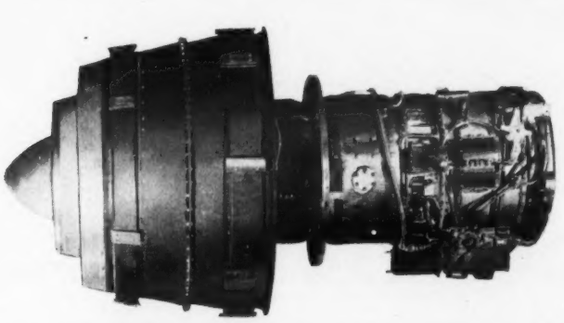

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Return to Earth

On August 11th, 1960, the first space vehicle to return safe and sound after several orbits was fished by the Americans from the Pacific Ocean. A week later they caught the instrument capsule of a second satellite as it flew through the air. And on August 20th *Sputnik V* landed the first "astronauts," alive and in good spirits, in the Soviet Union.

Compared with public reaction at the news of the first *Sputnik*, the repercussions of these events on the world at large were relatively slight. Yet it is no less significant an achievement to recover satellites from their orbits than to send them out into space.

Apart from the fact that safe return is essential to manned space flight, the recovery of unmanned instrument capsules opens up economic and scientific prospects which would be unthinkable with a non-recoverable vehicle—not to mention the military value of a weapon-carrying space vehicle guided to earth.

It is therefore no wonder that, as soon as they had succeeded in sending a few artificial satellites on their way, the two space Powers turned their efforts to the problem of bringing them back to earth.

It appears that even *Sputnik II*, which carried a dog, was designed as a re-entry vehicle. In the USA, the U. S. Air Force *Discoverer* programme was the first to envisage the return and recovery of a satellite capsule. After an early attempt in February, 1959, the Americans were near success with *Discoverer II* on April 14th. Although the capsule was brought onto a descent trajectory, it was not in the planned area, and was sighted descending by parachute near Spitsbergen, but not recovered. *Discoverer II* obviously stood up well to its re-entry into the atmosphere and can thus be considered the first satellite to return safely from orbit.

In May, 1960, the Russians launched a mighty space vehicle, weighing 10,000 pounds, with a human dummy and complete life support equipment on board. As the result of a fault in attitude control, however, *Sputnik IV*—claimed by the USSR to be the "first cosmic spaceship"—did not enter the planned descent trajectory, but remained in space.

The race became keener.

By this time the Americans had launched their eleventh *Discoverer* and had still not scored a success. Finally, after a further failure on June 29th, *Discoverers XIII* and *XIV* put them in front of the Soviet Union by a short head, although the satellites carried only 84 lb instrument capsules without living creatures.

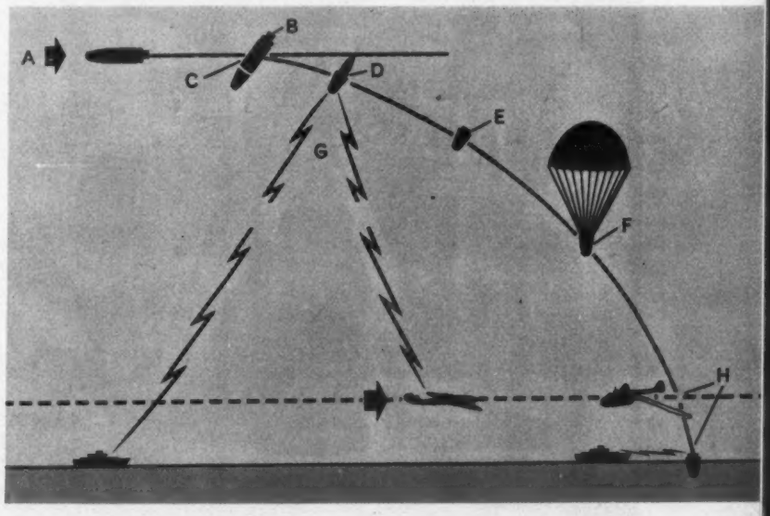
The recovery of a space vehicle is bedevilled by two problems, namely the initiation of a descent trajectory and the fierce heat generated by the vehicle on its return into atmosphere. Here, depending on the construction of the re-entry capsule—drag deceleration, vehicle with heat sink *(Discoverer, Mercury)* or winged glider with aerodynamic lift *(Dyna-Soar)*—there is an optimum descent trajectory at which friction heat is at a minimum. For space vehicles carrying men or animals, the high decelerations encountered during descent must not result in damage to the organism, a requirement which sets further limits to the number of possible trajectories. In addition to the pure deceleration forces themselves, the accelerations due to tumbling motions can endanger space travellers, and must be countered by reliable attitude stabilization during descent.

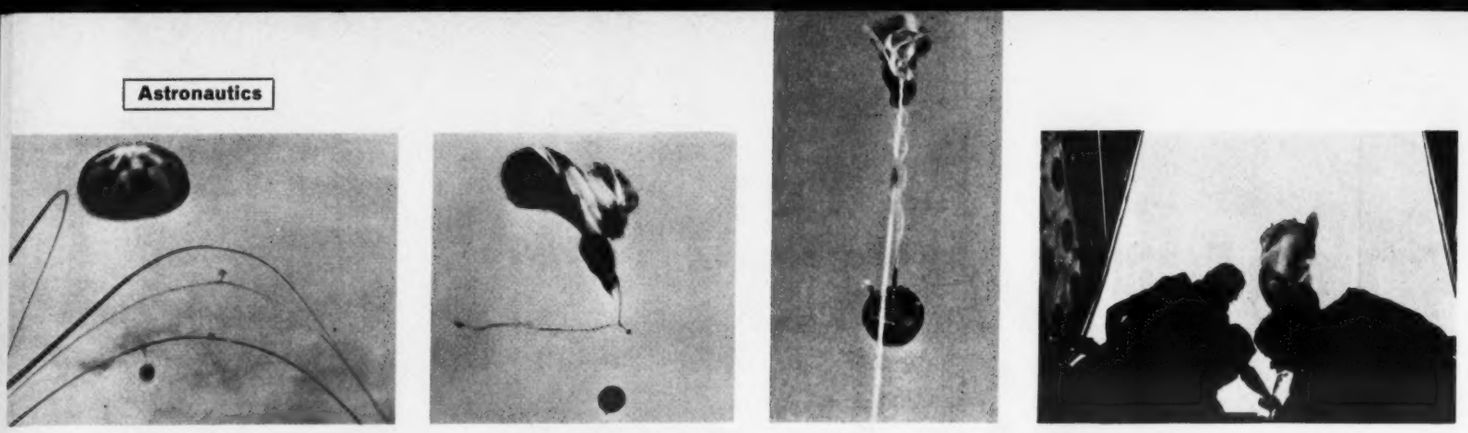
Preparations for the launching of Discoverer XIII. Before it is mounted on the Douglas *Thor* first stage (in background) the Lockheed *Agena* second stage is given a last check. *Discoverer XIII* was the first satellite to be recovered on its return to earth.

Finally, a number of other items of equipment are necessary for safe recovery—parachutes, signalling equipment, floatation mechanisms etc.

Only when one considers the great number of extreme conditions—heat, cold, accelerations, radiation etc.—to which all the vital systems and equipment of the space vehicle must be subjected, is it possible to appreciate the brilliance of the technical and scientific achievement of bringing an artificial satellite back from space unharmed.

How the Discoverer is retrieved. A time switch actuates control nozzles to turn the satellite, horizontally stabilized in orbit (A) with its nose to the earth (B). The re-entry capsule is then separated by explosive bolts and springs (C) and braked by a retro-rocket (D). As speed decreases, centrifugal force grows less, and the earth's gravity forces the capsule into a parabolic trajectory. After the capsule has re-entered the atmosphere (E), a parachute opens at a predetermined altitude (F) and floats the payload slowly to earth. In the meantime, aircraft or ships, guided by telemetry signals (G) from the capsule reach the spot at which it has landed and recover it (H).





Capture of Discoverer XIV. The looped cables towed by a Fairchild C-119 . . . engage with the parachute lines . . . and the instrument capsule can be pulled on board.

The American Discoverer experiments

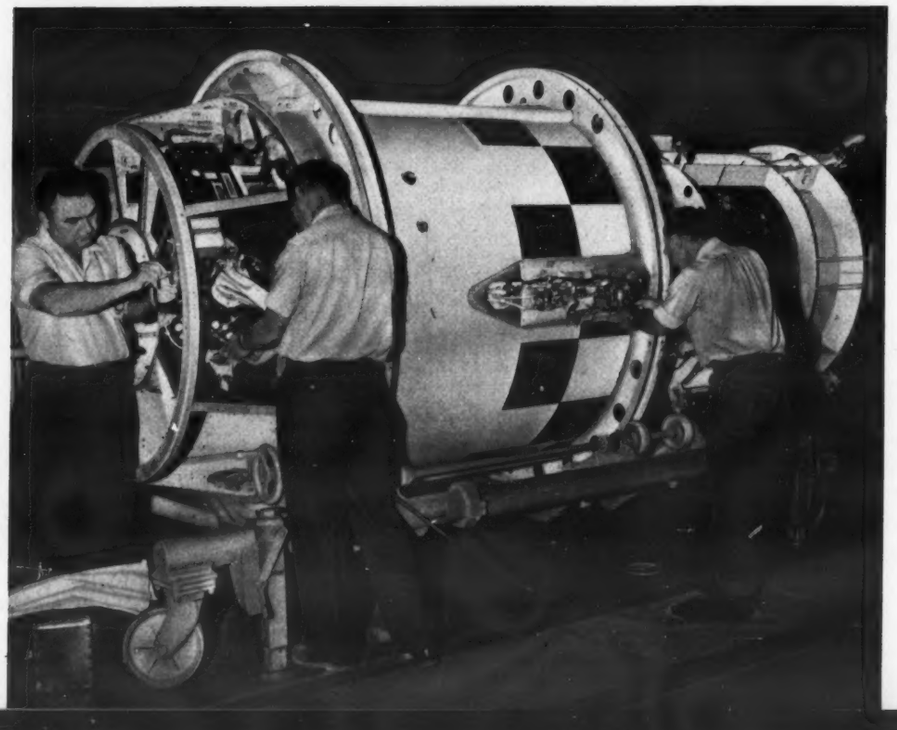
Thirteen is not always an unlucky number for everyone. The U. S. Air Force suffered twelve failures with its *Discoverer* programme before, at its thirteenth attempt, it added a new entry to the roll of honour of American astronautics.

Designed as the forerunners of observation satellites which would store data on board and bring them back to earth after a few orbits, the *Discoverers* serve primarily for tests of attitude control systems to stabilize the satellite with respect to the earth's surface, and for the development of re-entry capsules and their recovery devices. The first *Discoverer*, launched in a southerly direction by Douglas *Thor* from Vandenberg Air Force Base on February 28th, 1959, reached a near-polar orbit (inclination 87°). The stabilization device did not, however, work satisfactorily, and *Discoverer I* developed a tumbling motion in its orbit, finally burning up in the early days of March. On April 13th *Discoverer II* was launched; this was the first to be fitted with a re-entry capsule. Brought into its downward trajectory a few minutes prematurely by the time switch, the capsule, instead of coming down in the Pacific Ocean as planned, descended near Spitsbergen. All attempts at search were vain. *Discoverers III, IV, IX, X* and *XII* did not reach their polar orbits, others could not be stabilized or ejected their capsules at the wrong time . . . and even when all the other equipment worked, the parachute or radio beacon went on strike.

To trace the causes of these failures, the Lockheed engineers responsible for the *Discoverer* programme fitted the thirteenth satellite with additional measuring equipment. But *Discoverer XIII* punctually entered its descent trajectory over Alaska, just before completing its seventeenth orbit, and the parachute also opened as planned. Owing to bad weather, however, the attempt to recover the capsule in the air failed, and it fell into the sea, still transmitting radio signals, in the region of Hawaii, where it was recovered by a U. S. Navy frog-man operating from a helicopter. Owing to the flat re-entry trajectory, the 300-lb *Discoverer XIII* was subjected to high temperatures (of about 4,000 °F) for several minutes, but these did not reach the interior of the capsule, which was protected by the ablating nose cone.

One week later, the instrument capsule of *Discoverer XIV* was recovered as planned by a Fairchild C-119. The pilot twice missed his valuable booty, first by six inches, and then by two or three feet. On the third attempt, just before the capsule descended into a cloud at the rate of 1,500 ft/min, its parachute lines were caught by an arrester cable attached to a long pole, and it was pulled aboard the aircraft.

Recovery system of Discoverer XIII. Left, the folded parachute; right, the capsule lid with transmitting antenna and flashing lights.



Lockheed *Agena* second stage with Bell *Hustler* liquid-propellant engine delivering 15,000 lb thrust.

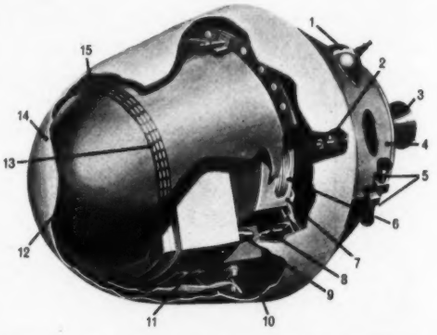


Diagram of a Discoverer re-entry vehicle. 1. cold gas storage tank; 2. explosive bolt; 3. retro-rocket; 4. thrust cone; 5. stabilization jets; 6. recovery parachute and chaff; 7. parachute cover; 8. explosive pistons; 9. flashing light; 10. afterbody cover; 11. instrumentation package; 12. radio beacon (inside); 13. dye markers; 14. ablating re-entry shield; 15. recovery capsule.

Astronautics

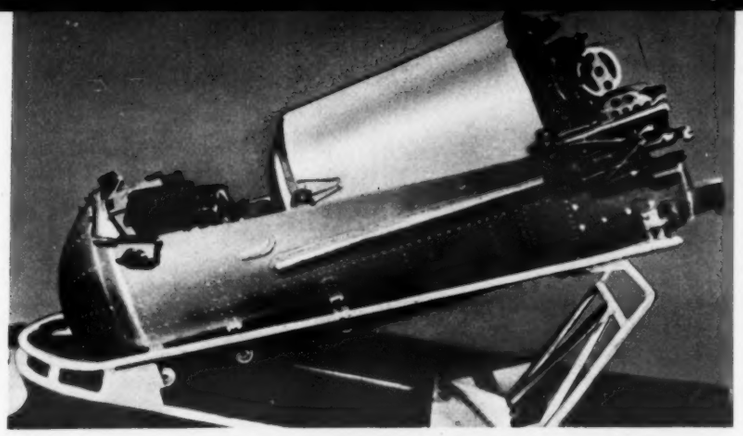
A second Noah's Ark

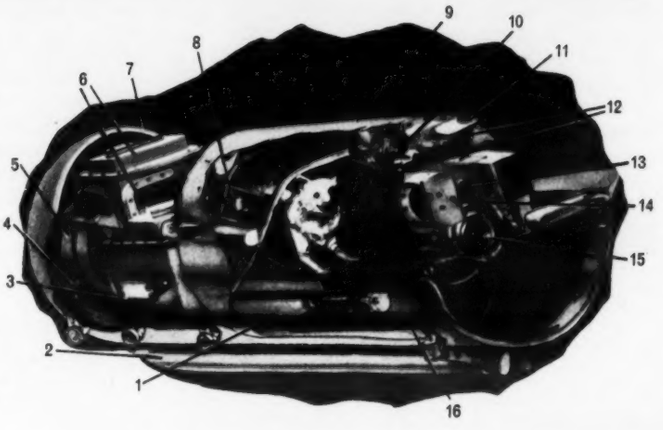
Two female dogs, forty mice, two rats and several hundred insects share the fame of being the first "astronauts" to return alive and healthy from space . . . not to mention the bacteria, fungi, algae, onions, peas, and grains of maize and wheat which were also sent around the earth in *Sputnik V* on August 19th, 1960, to land a day later on a field in a collective farm. Although in earlier experiments capsules containing living animals had been fired to great heights and recovered, these were not "true" space trips, as no orbit was reached.

As regards the booster, the Russians have as usual maintained a discreet silence, but it is generally assumed to be a variant of the ICBM tested over eastern Asia and the Pacific Ocean in January and July this year. Weighing 10,120 lb—without the last stage of the booster—*Sputnik V* is the heaviest space probe so far to be launched and, with the necessary modifications to the life support equipment, could reportedly have carried a man on board.

Sputnik's payload capsule was in two parts, an equipment chamber and a cabin. The latter contained the life support equipment, landing aids and all the living creatures. During the eighteenth pass on a nearly circular orbit—apogee 211 miles, perigee 190 miles—the descent phase was triggered by radio command. As the satellite entered the atmosphere, the equipment chamber separated from the cabin and burnt up, while the cabin itself was, according to official reports, "aerodynamically" braked. At a height of about 23,000 ft a barometric relay actuated a catapult, which ejected the container housing the two dogs and many of the other life forms. The container fell to earth at a speed of 20 to 26 ft/sec only six miles from the planned landing point.

As can be seen from the varied selection of living creatures carried in the satellite—which led a Soviet scientist to dub it "the Noah's Ark of space"—the experiment served primarily for the study of the biomedical aspects of space flight and the testing of life support equipment. Although monkeys more nearly resemble humans from the point of view of development, the Russians prefer dogs for space research, as they are easy to train and soon become accustomed to experimental environments; moreover, their main physiological systems—blood circulation and breathing—react in a similar way to changes in environment as do those of man.





View and sectioned drawing of the Sputnik V capsule. 1. pressure tank of the air regeneration unit; 2. catapult for ejecting capsule; 3. part of radio bearing transmitter; 4. batteries for heating microbe ampoules; 5. batteries; 6. scientific apparatus; 7. catapulted container; 8. catapult release; 9. cabin for animals; 10. microphone; 11. antenna of radio bearing transmitter; 12. valves; 13. television camera; 14. mirror; 15. part of ventilation system; 16. feeding automat.

With the aid of comprehensive medical apparatus, the following physiological data were measured: arterial pressure, heartbeats, breathing rate and body temperature; electrocardiograms were also taken. Two radio-controlled television cameras, one for each dog, observed their movements during the climb and descent phases and during the periods of the orbit when *Sputnik V* was in radio communication with the Soviet ground stations. The dogs were fed by an automat, which twice daily dispensed accurately measured portions of a gelatinous matter which contained all the necessary nutritive substances and the appropriate quantities of water. A similar automat had already proved its worth in *Sputnik II*, which carried the dog Laika.

The rats and mice took their solid food from feeding tubes fixed to the wire netting of their cages; water was fed to them on wicks. Mice and also the flies which were carried in ampoules are highly suitable for genetic research, as they multiply rapidly and exhibit a large number of hereditary traits. From observation of their descendants, conclusions will be drawn regarding the biological effects of high-altitude radiation. The plant seeds in *Sputnik V* will serve the same purpose.

In both the Soviet Union and the USA biologists are hard at work developing air regeneration systems for space vehicles. Not only must the oxygen consumed be replaced, but the carbon dioxide exhaled must be eliminated. For short space trips the simplest procedure would appear to be that employed in the breathing apparatus used by divers and high-altitude pilots: the supply of fresh oxygen from bottles and the chemical absorption of carbonic acid. If, however, a space trip lasts longer than eight or ten days, this solution is impractical for weight reasons. Here nature has found a way to solve the problem of air regeneration for space trips lasting months, or even years: the photosynthesis of plants, a process in which energy, in the form of light, causes plants to absorb the carbon from carbon dioxide, releasing pure oxygen. Laboratory tests have shown that only a few pounds of certain green algae (which cover a large area in relation to their weight) are enough to keep a man supplied with air. The algae carried in *Sputnik V* were designed to test whether they could perform this task under space flight conditions.

It is but one small step from *Sputnik V* to the manned earth satellite, though the Russians say that a few more experiments are to be made with animals to improve the reliability of the system before the first man is sent into space.

Safe and sound back from space: Strelka (left) and Byelka (right).

Catalogue of the Space Age II

Only three years have passed since *Sputnik I* began its journeys around the earth, soon to be followed by a whole "galaxy" of artificial heavenly bodies of all kinds and sizes. A first catalogue of launchings was published in *Interavia* No. 9, 1959, revealing that during the 21 months from October 4th, 1957 to June 25th, 1959 a total of 29 vehicles had been fired into space, not all of them successfully. The next fifteen months, covered in the present survey, saw no fewer than 35 attempts. Of these, 31 were made by the United States (a round dozen of them, however, being failures), while the Soviet Union successfully sent up four space probes. Doubtless there have also been failures on the Russian side, though no word of them has reached the public.

The new catalogue contains only those satellites and planetoids which actually went into orbit, since the list would otherwise have grown too long. On the other hand, additional information, such as launching point, launching weight of booster, etc., has been included this time. Finally, the diagram on page 1399 shows comparative sizes of the various types.

Whereas in their experiments the United States are pursuing a wide variety of objectives, both civil and military — from radiation measurements via geodetic and meteorogical research, passive and active transmission of messages and navigation assistance for ships and aircraft, to the early detection of ballistic missile launchings — the Soviet Union appears to be directing most of its efforts to the moon and towards manned space travel.

The Americans have won world-wide acclaim for their *Pioneer V*, *Tiros I*, *Transit IIA*, *Echo I* and *Discoverer XIV*. Radio signals from the *Pioneer V* paddle-wheel planetoid were received by the Jodrell Bank radio telescope from distances of up to 22.5 million miles or more. The *Tiros I* television cameras transmitted more then 22,000 cloud pictures. *Transit IIA*, launched into orbit

Survey of Successful Satellites and Space Probes

(Continued from *Interavia* No. 9, 1959; as at October, 1960)

Name Total orbit weight (W_t) Payload weight (W_p)	Launching date Lifetime Launch point	Booster Launching weight (W_L)	Payload	Objectives and results P = perigee, A = apogee I = inclination, T = orbital period
EXPLORER VI (USA) W_t = 143 lb	7 Aug 1959 1 year plus Cape Canaveral	Three-stage Thor-Able W_L = 105,000 lb	*Shape and dimensions:* spherical with four 7.9 ft paddle-shaped vanes for solar cells; diameter 26 in. *Equipment:* Telemetry instruments designed by Drs. Friedmann and Van Allen. *Transmitters:* two 40 W transmitters; frequencies 20 and 108 Mc/s; device for switching off after 1 year. *Power supply:* 9,600 solar cells plus nickel-cadmium batteries.	*Objectives:* measurement of radiation, heat and magnetic field strength, heavy nuclei in cosmic radiation and micrometeorite impacts. *Results:* orbit achieved (P = 157 mi; A = 26,378 mi; I = 46.9°; T = 12 h 30 min).
DISCOVERER V (USA) W_t = 1,700 lb W_p = 300 lb	13 Aug 1959 to 28 Sep 1959 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* cylindrical with nose cone; diameter 5 ft, length 19.2 ft. *Equipment:* telemetry and data recording instruments; retro-rocket, parachute, radio beacon, radar reflector, identification light. *Transmitter:* unknown; one directional antenna and one whip antenna. *Power supply:* nickel-cadmium batteries.	*Objectives:* attainment of a polar orbit; collection of data on propulsion, transmission of communications, orbital performance and stabilization; recovery of instrument capsule. *Results:* orbit achieved (P = 136 mi; A = 450 mi; T = 94 min). Instrument capsule separated from booster; not recovered as it was not sighted and the radio beacon was not working.
DISCOVERER VI (USA) W_t = 1,700 lb W_p = 300 lb	19 Aug 1959 to 20 Oct 1959 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* *Equipment:* *Transmitter:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 138 mi; A = 537 mi; T = 95.3 min). Not recovered.
LUNIK II (USSR) W_p = 858.4 lb	12 Sep 1959 to 13 Sep 1959 Kapustin Yar (?)	Not known, probably multi-stage rocket	*Shape:* spherical; of aluminium/magnesium alloy; diameter 3 ft 11 in. *Equipment:* measuring instruments. *Transmitters:* three in the satellite: frequencies 183.6 Mc/s, 39.986 Mc/s, 19.993 Mc/s. Two in the last stage: frequencies 20.003 Mc/s, 19.997 Mc/s. *Power supply:* not disclosed.	*Objectives:* measurement of internal temperature and pressure, earth and moon magnetic fields, particles and heavy nuclei of primary cosmic radiation. *Results:* impacted on the moon as planned.
VANGUARD III (USA) W_t = 100 lb W_p = 50 lb	18 Sep 1959 30 to 40 years Cape Canaveral	Three-stage Vanguard STV-7 W_L = 22,600 lb	*Shape:* spherical; of magnesium; diameter 20 in., with a 26 in. cylinder mounted on top; inseparable from third stage. *Equipment:* measuring instruments. *Transmitters:* One 30 mW transmitter, frequency 108 Mc/s; one 80 mW transmitter, frequency 108.03 Mc/s; four rod antennas. *Power supply:* silver-zinc batteries.	*Objectives:* measurement of the earth's magnetic field and solar X-rays; investigation of environmental conditions. *Results:* orbit achieved (P = 319 mi; A = 2,329 mi; I = 33.4°; T = 130 min).
LUNIK III (USSR)	4 Oct 1959 to 20 May 1960 Kapustin Yar (?)	Not known	*Shape:* cylindrical with hemispherical end bulkheads; of aluminium/magnesium alloy; diameter 3 ft 11 in., length 4 ft 3 in. *Equipment:* 35 mm cine-camera with 200 and 500 mm lenses; developer; television transmitter; measuring instruments. *Transmitters:* two: frequencies 39.986 Mc/s and 183.6 Mc/s; six rod antennas. *Power supply:* solar cells and chemical batteries.	*Objectives:* photography of back of moon, measurement of cosmic radiation, the moon's magnetic field and micrometeorite impacts. *Results:* photographed the moon as planned and is now circling the earth (P = 29,500 mi; A = 298,000 mi; T = 15 days).

along with the NRL satellite, proved its value as a navigation aid for shipping and aircraft, while *Echo I*, which enables radio communications to be made over thousands of miles, can be seen with the naked eye. Lastly, in the *Discoverer XIV* shot it was finally possible to recover the instrumentation capsule, as originally planned, during its descent through the air.

Every publicly-announced Soviet launching has been a hit, with the possible exception of the *Sputnik IV* whose pressure cabin, instead of returning to earth on ignition of the retro rockets, travelled a bit further away. *Lunik II* ended its relatively short journey in an impact on the moon. Its successor, *Lunik III*, travelled past the moon and photographed the hitherto unseen back of our natural satellite. And last triumph at the time of writing, *Sputnik V* brought two dogs and other animals, plants and instruments safely back to mother earth with unexcelled accuracy.

Yet, in recounting these outstanding performances, we should not ignore the failures. Often it has been merely some small defect which has tipped the balance away from success. The following is a brief description of the American satellites and planetoids which did not go into orbit:

Explorer (no number): launched by a *Juno II* on July 16th, 1959, for the purpose of radiation measurements. The booster had to be destroyed by the range safety officer soon after launch. In a second *Explorer* (again without number) on March 23rd, 1960, the third or fourth stage failed to ignite.

Beacon: launched on August 14th, 1959 by a modified three-stage *Juno II*. This balloon satellite (diameter 12 ft) was designed to measure air densities. Did not go into orbit because the propellant burned out prematurely, and the attitude control in the upper stages did not function.

Transit I: fired by a *Thor-Able* on September 17th, 1959; third stage failed to ignite, therefore no orbit reached. *Transit I* was scheduled to investigate the use of satellites as navigation aids.

Pioneer (no number): launched on November 26th, 1959, by an *Atlas-Able;* was supposed to scan the moon electronically from a distance of some 5,000 miles, but did not get far, as the nose casing fell off as a result of excessive vibration, and the second stage failed to ignite.

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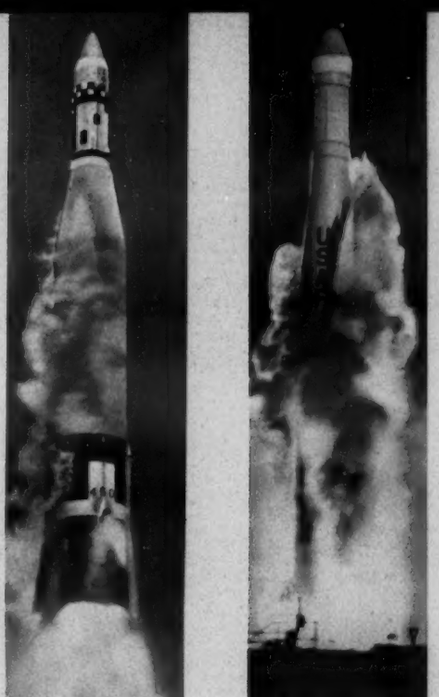
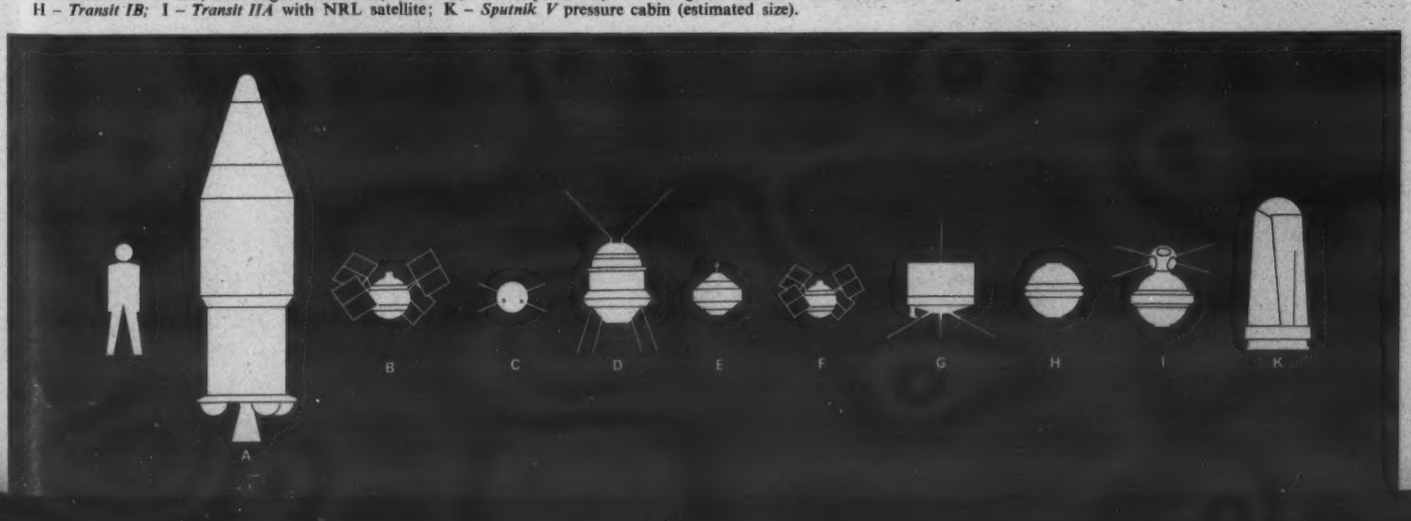


Left: This *Atlas-Agena* put the *Midas II* early warning satellite into orbit. *Right:* The *Thor-Able Star* put two satellites, the *Transit IIA* and the NRL satellite, into orbit at one and the same time.

Name Total orbit weight (W_t) Payload weight (W_p)	Launching date Lifetime Launch point	Booster Launching weight (W_L)	Payload	Objectives and results P = perigee, A = apogee I = inclination, T = orbital period
EXPLORER VII (USA) W_p = 91.5 lb	13 Oct 1959 2 years Cape Canaveral	Four-stage Juno II W_L = 120,000 lb	*Shape:* toroid, of plastic; 30×30 in. *Equipment:* measuring instruments. *Transmitters:* two: frequencies 20 and 108 Mc/s; can be switched off after one year; 4 whip antennas and 4 telescoping rod antennas. *Power supply:* solar cells and chemical batteries.	*Objectives:* measurement of heat radiation of sun and earth; Lyman-Alpha rays, soft solar X-rays; and micrometeorite impacts. *Results:* orbit achieved (P = 344.5 mi; A = 677.9 mi; I = 50.3°; T = 101.35 min).
DISCOVERER VII (USA) W_t = 1,700 lb W_p = 300 lb	7 Nov 1959 to 26 Nov 1959 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* *Equipment:* *Transmitters:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 104 mi; A = 550 mi; T = 95 min). Owing to the failure of a transformer the satellite could not be fully stabilized in orbit (infra-red scanner received no current); instrument capsule did not separate as planned.
DISCOVERER VIII (USA) W_t = 1,700 lb W_p = 300 lb	20 Nov 1959 to 8 Mar 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* *Equipment:* *Transmitters:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 120 mi; A = 1,000 mi; T = 103.72 min). Instrument capsule re-entered atmosphere; radio beacon operated until parachute unfolded. Owing to the highly elliptical orbit, however, the stabilizer used up the gas supplies prematurely; the satellite was thus in the wrong position when the capsule separated, so that the latter fell several hundred miles beyond the recovery area.

These silhouettes (scale 1:100) give an idea of the comparative sizes of the following artificial satellites:

A – *Discoverer V* and, with slight differences, *Midas II;* B – *Explorer VI;* C – *Vanguard III;* D – *Lunik III;* E – *Explorer VII;* F – *Pioneer V* (planetoid); G – *Tiros I;* H – *Transit IB;* I – *Transit IIA* with NRL satellite; K – *Sputnik V* pressure cabin (estimated size).



Catalogue of the Space Age II

Only three years have passed since *Sputnik I* began its journeys around the earth, soon to be followed by a whole "galaxy" of artificial heavenly bodies of all kinds and sizes. A first catalogue of launchings was published in *Interavia* No. 9, 1959, revealing that during the 21 months from October 4th, 1957 to June 25th, 1959 a total of 29 vehicles had been fired into space, not all of them successfully. The next fifteen months, covered in the present survey, saw no fewer than 35 attempts. Of these, 31 were made by the United States (a round dozen of them, however being failures), while the Soviet Union successfully sent up four space probes. Doubtless there have also been failures on the Russian side, though no word of them has reached the public.

The new catalogue contains only those satellites and planetoids which actually went into orbit, since the list would otherwise have grown too long. On the other hand, additional information, such as launching point, launching weight of booster, etc., has been included this time. Finally, the diagram on page 1399 shows comparative sizes of the various types.

Whereas in their experiments the United States are pursuing a wide variety of objectives, both civil and military — from radiation measurements via geodetic and meteorogical research, passive and active transmission of messages and navigation assistance for ships and aircraft, to the early detection of ballistic missile launchings — the Soviet Union appears to be directing most of its efforts to the moon and towards manned space travel.

The Americans have won world-wide acclaim for their *Pioneer V, Tiros I, Transit IIA, Echo I* and *Discoverer XIV*. Radio signals from the *Pioneer V* paddle-wheel planetoid were received by the Jodrell Bank radio telescope from distances of up to 22.5 million miles or more. The *Tiros I* television cameras transmitted more then 22,000 cloud pictures. *Transit IIA*, launched into orbit

Survey of Successful Satellites and Space Probes

(Continued from *Interavia* No. 9, 1959; as at October, 1960)

Name **Total orbit weight (W_t)** **Payload weight (W_p)**	**Launching date** **Lifetime** **Launch point**	**Booster** **Launching weight (W_L)**	**Payload**	**Objectives and results** **P = perigee, A = apogee** **I = inclination, T = orbital period**
EXPLORER VI (USA) **W_t = 143 lb**	7 Aug 1959 1 year plus Cape Canaveral	**Three-stage Thor-Able** **W_L = 105,000 lb**	*Shape and dimensions:* spherical with four 7.9 ft paddle-shaped vanes for solar cells; diameter 26 in. *Equipment:* Telemetry instruments designed by Drs. Friedmann and Van Allen. *Transmitters:* two 40 W transmitters; frequencies 20 and 108 Mc/s; device for switching off after 1 year. *Power supply:* 9,600 solar cells plus nickel-cadmium batteries.	*Objectives:* measurement of radiation, heat and magnetic field strength, heavy nuclei in cosmic radiation and micrometeorite impacts. *Results:* orbit achieved (P = 157 mi; A = 26,378 mi; I = 46.9°; T = 12 h 30 min).
DISCOVERER V (USA) **W_t = 1,700 lb** **W_p = 300 lb**	13 Aug 1959 to 28 Sep 1959 Vandenberg AFB	**Two-stage Thor-Agena** **W_L = 100,000 lb**	*Shape:* cylindrical with nose cone; diameter 5 ft, length 19.2 ft. *Equipment:* telemetry and data recording instruments; retro-rocket, parachute, radio beacon, radar reflector, identification light. *Transmitter:* unknown; one directional antenna and one whip antenna. *Power supply:* nickel-cadmium batteries.	*Objectives:* attainment of a polar orbit; collection of data on propulsion, transmission of communications, orbital performance and stabilization; recovery of instrument capsule. *Results:* orbit achieved (P = 136 mi; A = 450 mi; T = 94 min). Instrument capsule separated from booster; not recovered as it was not sighted and the radio beacon was not working.
DISCOVERER VI (USA) **W_t = 1,700 lb** **W_p = 300 lb**	19 Aug 1959 to 20 Oct 1959 Vandenberg AFB	**Two-stage Thor-Agena** **W_L = 100,000 lb**	*Shape:* *Equipment:* *Transmitter:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 138 mi; A = 537 mi; T = 95.3 min). Not recovered.
LUNIK II (USSR) **W_p = 858.4 lb**	12 Sep 1959 to 13 Sep 1959 Kapustin Yar (?)	**Not known, probably multi-stage rocket**	*Shape:* spherical; of aluminium/magnesium alloy; diameter 3 ft 11 in. *Equipment:* measuring instruments. *Transmitters:* three in the satellite: frequencies 183.6 Mc/s, 39.986 Mc/s, 19.993 Mc/s. Two in the last stage: frequencies 20.003 Mc/s, 19.997 Mc/s. *Power supply:* not disclosed.	*Objectives:* measurement of internal temperature and pressure, earth and moon magnetic fields, particles and heavy nuclei of primary cosmic radiation. *Results:* impacted on the moon as planned.
VANGUARD III (USA) **W_t = 100 lb** **W_p = 50 lb**	18 Sep 1959 30 to 40 years Cape Canaveral	**Three-stage Vanguard STV-7** **W_L = 22,600 lb**	*Shape:* spherical; of magnesium; diameter 20 in., with a 26 in. cylinder mounted on top; inseparable from third stage. *Equipment:* measuring instruments. *Transmitters:* One 30 mW transmitter, frequency 108 Mc/s; one 80 mW transmitter, frequency 108.03 Mc/s; four rod antennas. *Power supply:* silver-zinc batteries.	*Objectives:* measurement of the earth's magnetic field and solar X-rays; investigation of environmental conditions. *Results:* orbit achieved (P = 319 mi; A = 2,329 mi; I = 33.4°; T = 130 min).
LUNIK III (USSR)	4 Oct 1959 to 20 May 1960 Kapustin Yar (?)	**Not known**	*Shape:* cylindrical with hemispherical end bulkheads; of aluminium/magnesium alloy; diameter 3 ft 11 in., length 4 ft 3 in. *Equipment:* 35 mm cine-camera with 200 and 500 mm lenses; developer; television transmitter; measuring instruments. *Transmitters:* two: frequencies 39.986 Mc/s and 183.6 Mc/s; six rod antennas. *Power supply:* solar cells and chemical batteries.	*Objectives:* photography of back of moon, measurement of cosmic radiation, the moon's magnetic field and micrometeorite impacts. *Results:* photographed the moon as planned and is now circling the earth (P = 29,500 mi; A = 298,000 mi; T = 15 days).

along with the NRL satellite, proved its value as a navigation aid for shipping and aircraft, while *Echo I*, which enables radio communications to be made over thousands of miles, can be seen with the naked eye. Lastly, in the *Discoverer XIV* shot it was finally possible to recover the instrumentation capsule, as originally planned, during its descent through the air.

Every publicly-announced Soviet launching has been a hit, with the possible exception of the *Sputnik IV* whose pressure cabin, instead of returning to earth on ignition of the retro rockets, travelled a bit further away. *Lunik II* ended its relatively short journey in an impact on the moon. Its successor, *Lunik III*, travelled past the moon and photographed the hitherto unseen back of our natural satellite. And last triumph at the time of writing, *Sputnik V* brought two dogs and other animals, plants and instruments safely back to mother earth with unexcelled accuracy.

Yet, in recounting these outstanding performances, we should not ignore the failures. Often it has been merely some small defect which has tipped the balance away from success. The following is a brief description of the American satellites and planetoids which did not go into orbit:

Explorer (no number): launched by a *Juno II* on July 16th, 1959, for the purpose of radiation measurements. The booster had to be destroyed by the range safety officer soon after launch. In a second *Explorer* (again without number) on March 23rd, 1960, the third or fourth stage failed to ignite.

Beacon: launched on August 14th, 1959 by a modified three-stage *Juno II*. This balloon satellite (diameter 12 ft) was designed to measure air densities. Did not go into orbit because the propellant burned out prematurely, and the attitude control in the upper stages did not function.

Transit I: fired by a *Thor-Able* on September 17th, 1959; third stage failed to ignite, therefore no orbit reached. *Transit I* was scheduled to investigate the use of satellites as navigation aids.

Pioneer (no number): launched on November 26th, 1959, by an *Atlas-Able;* was supposed to scan the moon electronically from a distance of some 5,000 miles, but did not get far, as the nose casing fell off as a result of excessive vibration, and the second stage failed to ignite.

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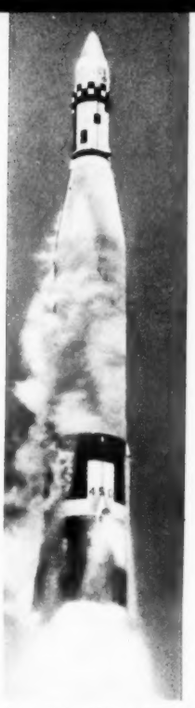

Left: This *Atlas-Agena* put the *Midas II* early warning satellite into orbit. *Right:* The *Thor-Able Star* put two satellites, the *Transit IIA* and the NRL satellite, into orbit at one and the same time.

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EXPLORER VII (USA) W_p = 91.5 lb	13 Oct 1959 2 years Cape Canaveral	Four-stage Juno II W_L = 120,000 lb	*Shape:* toroid, of plastic; 30×30 in. *Equipment:* measuring instruments. *Transmitters:* two: frequencies 20 and 108 Mc/s; can be switched off after one year; 4 whip antennas and 4 telescoping rod antennas. *Power supply:* solar cells and chemical batteries.	*Objectives:* measurement of heat radiation of sun and earth; Lyman-Alpha rays, soft solar X-rays; and micrometeorite impacts. *Results:* orbit achieved (P = 344.5 mi; A = 677.9 mi; I = 50.3°; T = 101.35 min).
DISCOVERER VII (USA) W_t = 1,700 lb W_p = 300 lb	7 Nov 1959 to 26 Nov 1959 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* *Equipment:* *Transmitters:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 104 mi; A = 550 mi; T = 95 min). Owing to the failure of a transformer the satellite could not be fully stabilized in orbit (infra-red scanner received no current); instrument capsule did not separate as planned.
DISCOVERER VIII (USA) W_t = 1,700 lb W_p = 300 lb	20 Nov 1959 to 8 Mar 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 100,000 lb	*Shape:* *Equipment:* *Transmitters:* *Power supply:* } as Discoverer V	*Objectives:* as Discoverer V. *Results:* orbit achieved (P = 120 mi; A = 1,000 mi; T = 103.72 min). Instrument capsule re-entered atmosphere; radio beacon operated until parachute unfolded. Owing to the highly elliptical orbit, however, the stabilizer used up the gas supplies prematurely; the satellite was thus in the wrong position when the capsule separated, so that the latter fell several hundred miles beyond the recovery area.

These silhouettes (scale 1:100) give an idea of the comparative sizes of the following artificial satellites:

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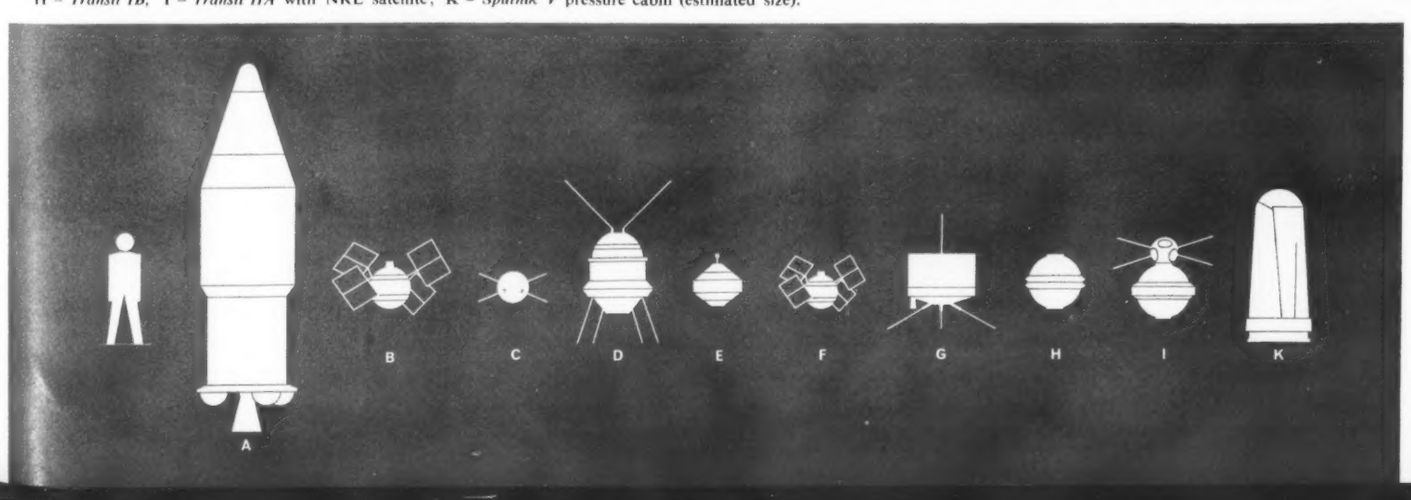

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PIONEER V (USA) W_p = 94.8 lb	11 Mar 1960 100,000 years; useful life was 106 days Cape Canaveral	Three-stage Thor-Able W_L = 105,000 lb	*Shape:* spherical, with four paddle-shaped vanes for solar cells; diameter 26 in. *Equipment:* instruments to test tracking facilities for the Transit navigation satellites; six external lights, not visible to the naked eye; doppler radar test equipment; weight of instruments 40 lb. *Transmitters:* one 5 W and one 150 W; frequency 378 Mc/s. *Power supply:* 4,800 solar cells charging 28 nickel-cadmium batteries.	*Objectives:* to probe interplanetary space between the orbits of earth and Venus; long-range communication experiments; to study methods of measuring astronomical distances; to collect data on plasmas, cosmic radiation, charged solar particles, magnetic fields, temperatures and micrometeorite impacts. *Results:* Solar orbit achieved (perihelion 74.9 million mi; aphelion 92.3 million mi; inclination to ecliptic 3.35°; orbital period 311.6 days; speed on burnout of third stage 24,689 m.p.h.). Measured energy and density of particles, magnetic fields and the effects of solar flares. Radio contact maintained until June 26th, when Pioneer V had transmitted for 138.6 h; distance from earth 22.5 million mi.
TIROS I (USA) W_p = 270 lb	1 Apr 1960 50–100 years; useful life 78 days Cape Canaveral	Three-stage Thor-Able W_L = 150,000 lb	*Shape:* drum; aluminium and stainless steel; diameter 42 in., height 19 in. *Equipment:* one wide and one narrow angle camera with tape recorders, device for immediate or delayed picture transmission (on command); two pairs of rockets for spin stabilization. *Transmitters:* two frequency-modulated 2 W transmitters for picture transmission, frequency 235 Mc/s; two 30 mW beacons for tracking, frequencies 108 and 108.03 Mc/s; four dipole antennas for transmission, one dipole for reception. *Power supply:* 9,200 solar cells on top and sides; nickel-cadmium batteries.	*Objectives:* testing of television equipment for a world-wide meteorological information system. *Results:* orbit achieved (P = 429.7 mi; A = 467.4 mi; I = 48.3°; T = 99.2 min; speed at burnout of third stage = 16,809 m.p.h.). Television equipment sent more than 22,000 cloud pictures back to earth.
TRANSIT 1B (USA) W_p = 265 lb	13 Apr 1960 16 months Cape Canaveral	Two-stage Thor-Able Star; second stage with gimballed re-igniting Aerojet-General motor	*Shape:* spherical; plastic; diameter 36 in.; two triangular bulges for solar batteries. *Equipment:* Two ultra-stable oscillators in temperature-resistant Dewar flasks; infra-red scanner to measure rotation; two telemetering receivers and transmitters. *Transmitters:* Frequencies 54, 324, 162 and 216 Mc/s; spiral ribbon antenna. *Power supply:* Solar cells and nickel-cadmium batteries, also silver-zinc batteries.	*Objectives:* Testing of equipment for all-weather navigation by ships and aircraft. *Results:* Orbit achieved (P = 233 mi; A = 479 mi; I = 51°; T = 96 min; speed on reaching orbit 16,590 m.p.h.). Proved feasible as navigation system.
DISCOVERER X (USA) W_t = 1,700 lb W_p = 300 lb	15 Apr 1960 to 26 Apr 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* As Discoverer V. *Equipment:* As Discoverer V; plus 10-lb instrument capsule in Agena for tests under the Transit programme. Capsule contained doppler beacon, flares, etc. *Transmitters:* As Discoverer V. *Power supply:* As Discoverer V.	*Objectives:* As Discoverer V. *Results:* Orbit achieved (P = 109 mi; A = 380 mi; I = 80.1°; T = 92.25 min). Instrument capsule ejected but re-entry not observed; no attempt at recovery.
SPUTNIK IV (USSR) W_t = 10,008 lb W_p = 5,512 lb	15 May 1960 Relatively short Aralsk (?)	Multi-stage rocket; no details known	*Shape:* In two parts. *Equipment:* Human dummy; life support equipment; tape recorders; retro-rockets; weight of instruments 3,250 lb. *Transmitter:* One transmitter for both telemetering and voice communication; frequency 19.995 Mc/s. *Power supply:* Solar cells and chemical batteries.	*Objectives:* Testing of equipment for manned space travel and attempt at recovery of a pressure cabin. *Results:* Orbit achieved (P = 188.5 mi; A = 228.7 mi; I = 64.9°; T = 91.1 min; speed on burnout of last stage = 17,300 m.p.h.). Owing to faulty attitude of satellite, the retro-rockets took the capsule into a new orbit (P = 191 mi; A = 429 mi; T = 94.25 min), instead of bringing it back to earth. Spoken messages stored on tape and received on earth.
MIDAS II (USA) W_t = 5,000 lb	24 May 1960 40 months Cape Canaveral	Two-stage Atlas-Agena W_L = 260,000 lb	*Shape:* Cylindrical; diameter 5 ft, height 22 ft. *Equipment:* Infra-red, telemetering and data transmission equipment. *Transmitters:* not known. *Power supply:* Chemical batteries.	*Objectives:* Testing of a system to detect missile launchings with the aid of infra-red sensors. *Results:* Orbit achieved (P = 282 mi; A = 322 mi; I = 33°; T = 94.3 min). Equipment for transmitting data from infra-red sensors failed two days after launching.
TRANSIT IIA + NRL SATELLITE (USA) W_p Transit IIA = 223 lb W_p NRL = 42 lb	22 Jun 1960 50 years Cape Canaveral	Two-stage Thor-Able Star W_L = 105,000 lb	**Transit IIA** *Shape:* Spherical with rings for solar cells; of plastic; diameter 36 in. *Equipment:* Two ultra-stable oscillators; infra-red sensors to detect satellite rotation; electronic clock as time standard; measuring instruments; receiver (Canadian). *Transmitters:* Four, frequencies 54, 324, 162 and 216 Mc/s; spiral ribbon antenna. *Power supply:* Solar cells and nickel-cadmium batteries. **NRL Satellite** *Shape:* Spherical; diameter 20 in. *Equipment:* Measuring instruments. *Transmitter:* One transmitter on 108 Mc/s; four whip antennas. *Power supply:* Solar cells and nickel-cadmium batteries.	**Transit IIA** *Objectives:* Testing the value of satellites as navigation aids for aircraft and ships; improving accuracy of geodetic measurements; provision of time standard; measurement of galactic noise. **NRL Satellite** *Objectives:* Measuring solar radiation (Lyman-Alpha and X-rays). *Results:* Orbit achieved (P = 389 mi; A = 665 mi; I = 66.7°; T = 101.7 min). Each satellite is separated, following the same trajectory, both are transmitting data.

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DISCOVERER XIII (USA) W_t = 1,700 lb W_p = 300 lb	10 Aug 1960 to 11 Aug 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* As Discoverer V; instrumentation capsule diameter 33 in., length 27 in. *Equipment:* As Discoverer V, plus telemetering equipment to determine the reasons for re-entry errors in earlier tests; number of telemetry check points increased by almost 400 %. *Transmitters:* } As Discoverer V *Power supply:* }	*Objectives:* As Discoverer V, plus testing of new systems, equipment, components, materials and construction techniques. *Results:* Orbit achieved (P = 161 mi; A = 436 mi; I = 82° 51'; T = 94.1 min; speed on reaching orbit 17,614 m.p.h.), capsule ejected and recovered from Pacific.
ECHO I (USA) W_p = 166 lb	12 Aug 1960 unlimited Cape Canaveral	Three-stage Thor-Delta W_L = 112,000 lb	*Shape:* Spherical; balloon of Mylar plastic with aluminium coating; diameter inflated 100 ft; balloon container spherical, diameter 26.5 in., of magnesium. *Equipment:* None. *Transmitters:* On balloon, two beacons for tracking; diameter 10 in., thickness ⅜ in., weight 11 oz; 10 mW; frequency 107.94 Mc/s. In third stage, one beacon for telemetering. 60 mW; frequency 108.06 Mc/s. *Power supply:* On balloon, 70 solar cells and five nickel-cadmium batteries per beacon. In third stage, mercury batteries.	*Objectives:* Investigation of the feasibility of world-wide communication satellites. Aluminium coating designed to reflect 98 % of radio waves up to a frequency of 20,000 Mc/s. *Results:* Orbit achieved (P = 945 mi; A = 1,049 mi; I = 47.2°; T = 118.3 min; speed at P = 15,973 m.p.h. at A = 15,643 m.p.h.). Voice communications carried out, e.g., between Holmdel, New Jersey, and Goldstone, California.
DISCOVERER XIV (USA) W_t = 1,700 lb W_p = 300 lb	18 Aug 1960 to 19 Aug 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* as Discoverer XIII. *Equipment:* As Discoverer XIII, plus additional equipment weighing 10 lb, including doppler beacon and external lights. *Transmitters:* As Discoverer XIII. *Power supply:* As Discoverer XIII.	*Objectives:* As Discoverer XIII; also measurements within Transit programme. *Results:* Orbit achieved (P = 187 mi; A = 502 mi; I = 79.6°; T = 94.5 min). Instrument capsule captured by a Fairchild C-119 in flight, at an altitude of 8,000 ft, 360 mi southwest of Honolulu.
SPUTNIK V (USSR) W_p = 10,120 lb	19 Aug 1960 to 20 Aug 1960 Aralsk (?)	Not known, probably multi-stage rocket of up to 1,000,000 lb thrust	*Shape:* In two parts; pressure capsule conical with rounded end. *Equipment:* Capsule containing two dogs, two rats, forty mice, flies, plants, fungi, microscopic water plants, seeds, photo emulsions; television camera for observation of animals; braking device. *Transmitters:* Number not known; frequency 19.995 Mc/s. *Power supply:* Not known.	*Objectives:* Testing of pressure capsule and recovery equipment; light measurements and investigation of heavy nuclei in the primary cosmic radiation, ultra-violet radiation from the sun and radiation inside pressure capsule. *Results:* Orbit achieved (P = 190 mi; A = 211 mi; I = 64° 57'; T = 90.72 min); capsule and carrier stage recovered after 18th orbit and 437,500 mi travel; landing occurred some 6 mi from scheduled point.
DISCOVERER XV (USA) W_t = 1,700 lb W_p = 300 lb	13 Sep 1960 to 14 Sep 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* *Equipment:* *Transmitters:* *Power supply:* } As Discoverer XIII	*Objectives:* As Discoverer XIII. *Results:* Orbit achieved, data not known. Instrument capsule sighted in Pacific after re-entry, some 200 mi N of Christmas Island (935 mi from scheduled impact area); recovery attempts unsuccessful.
COURIER IB (USA) W_p = 500 lb	4 Oct 1960 Several years Cape Canaveral	Two-stage Thor-Able Star W_L = 105,000 lb	*Shape:* Spherical; diameter 51 in. *Equipment:* Five tape recorders for data storage, daily capacity 3.4 million words. *Transmitters:* VHF and microwave transmitters, VHF beacon. *Power supply:* 19,152 solar cells, plus nickel-cadmium batteries (12 Ah, 28 V).	*Objectives:* Testing of feasibility of satellites for a global military communications network, to receive and store messages for later retransmission on command. *Results:* Orbit achieved (P = 500 mi; A = 750 mi); two ground stations for transmission and reception: Fort Monmouth, New Jersey, and Puerto Rico.

Vandenberg AFB, California, by *Thor-Agena*. The satellites did not go into orbit, as the booster vehicle in one case was damaged during launch, in another deviated from course and in the third failed to achieve the required burnout speed.

The interior of the unsuccessful *Pioneer VI* moon satellite. Instruments and radio equipment are grouped around the fuel tank.

Midas I: left Cape Canaveral on February 26th 1960 aboard an *Atlas-Agena* and was designed to trace ballistic missile firings with the aid of infra-red sensors. The second stage is believed to have failed to separate from the first.

Echo (no number): launched on May 13th, 1960 by a *Thor-Delta*. Second stage attitude control failed, and the third stage received no ignition signal from the ground.

Courier IA: fired on August 18th, 1960 by a *Thor-Able Star;* intended to test the feasibility of a global military communications system. The booster rocket exploded two and a half minutes after launch.

Pioneer VI was launched from Cape Canaveral by a three-stage *Atlas-Able* on September 25th, 1960; second stage, however, did not function correctly. This satellite was scheduled to circuit the moon for measurement purposes.

■

So much for the present survey. Competition in space is likely to get still more fierce in the years to come . . . and still more costly. The next survey may well report on the first return of a man from space. Let us hope, finally, that despite its enticing military aspects, astronautics will be used primarily to make a better world for all. ◆◆

Full-scale model of the *Courier IB*.

Name Total orbit weight (W_t) Payload weight (W_p)	Launching date Lifetime Launch point	Booster Launching weight (W_L)	Payload	Objectives and results P = perigee, A = apogee I = inclination, T = orbital period
PIONEER V **(USA)** W_p = 94.8 lb	11 Mar 1960 100,000 years; useful life was 106 days Cape Canaveral	Three-stage Thor-Able W_L = 105,000 lb	*Shape:* spherical, with four paddle-shaped vanes for solar cells; diameter 26 in. *Equipment:* instruments to test tracking facilities for the Transit navigation satellites; six external lights, not visible to the naked eye; doppler radar test equipment; weight of instruments 40 lb. *Transmitters:* one 5 W and one 150 W; frequency 378 Mc/s. *Power supply:* 4,800 solar cells charging 28 nickel-cadmium batteries.	*Objectives:* to probe interplanetary space between the orbits of earth and Venus; long-range communication experiments; to study methods of measuring astronomical distances; to collect data on plasmas, cosmic radiation, charged solar particles, magnetic fields, temperatures and micrometeorite impacts. *Results:* Solar orbit achieved (perihelion 74.9 million mi; aphelion 92.3 million mi; inclination to ecliptic 3.35°; orbital period 311.6 days; speed on burnout of third stage 24,689 m.p.h.). Measured energy and density of particles, magnetic fields and the effects of solar flares; radio contact maintained until June 26th, when Pioneer V had transmitted for 138.6 h; distance from earth 22.5 million mi.
TIROS I **(USA)** W_p = 270 lb	1 Apr 1960 50–100 years; useful life 78 days Cape Canaveral	Three-stage Thor-Able W_L = 150,000 lb	*Shape:* drum; aluminium and stainless steel; diameter 42 in., height 19 in. *Equipment:* one wide and one narrow angle camera with tape recorders, device for immediate or delayed picture transmission (on command); two pairs of rockets for spin stabilization. *Transmitters:* two frequency-modulated 2 W transmitters for picture transmission, frequency 235 Mc/s; two 30 mW beacons for tracking, frequencies 108 and 108.03 Mc/s; four dipole antennas for transmission, one dipole for reception. *Power supply:* 9,200 solar cells on top and sides; nickel-cadmium batteries.	*Objectives:* testing of television equipment for a world-wide meteorological information system. *Results:* orbit achieved (P = 429.7 mi; A = 467.4 mi; I = 48.3°; T = 99.2 min; speed at burnout of third stage = 16,809 m.p.h.). Television equipment sent more than 22,000 cloud pictures back to earth.
TRANSIT IB **(USA)** W_p = 265 lb	13 Apr 1960 16 months Cape Canaveral	Two-stage Thor-Able Star; second stage with gimballed re-igniting Aerojet-General motor	*Shape:* spherical; plastic; diameter 36 in.; two triangular bulges for solar batteries. *Equipment:* Two ultra-stable oscillators in temperature-resistant Dewar flasks; infra-red scanner to measure rotation; two telemetering receivers and transmitters. *Transmitters:* Frequencies 54, 324, 162 and 216 Mc/s; spiral ribbon antenna. *Power supply:* Solar cells and nickel-cadmium batteries, also silver-zinc batteries.	*Objectives:* Testing of equipment for all-weather navigation by ships and aircraft. *Results:* Orbit achieved (P = 233 mi; A = 479 mi; I = 51°; T = 96 min; speed on reaching orbit 16,590 m.p.h.). Proved feasible as navigation system.
DISCOVERER XI **(USA)** W_t = 1,700 lb W_p = 300 lb	15 Apr 1960 to 26 Apr 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* As Discoverer V. *Equipment:* As Discoverer V; plus 10-lb instrument capsule in Agena for tests under the Transit programme. Capsule contained doppler beacon, flares, etc. *Transmitters:* As Discoverer V. *Power supply:* As Discoverer V.	*Objectives:* As Discoverer V. *Results:* Orbit achieved (P = 109 mi; A = 380 mi; I = 80.1°; T = 92.25 min). Instrument capsule ejected, but re-entry not observed; no attempt at recovery.
SPUTNIK IV **(USSR)** W_t = 10,008 lb W_p = 5,512 lb	15 May 1960 Relatively short Aralsk (?)	Multi-stage rocket, no details known	*Shape:* In two parts. *Equipment:* Human dummy; life support equipment; tape recorders; retro-rockets; weight of instruments 2,250 lb. *Transmitter:* One transmitter for both telemetering and voice communication; frequency 19.995 Mc/s. *Power supply:* Solar cells and chemical batteries.	*Objectives:* Testing of equipment for manned space travel and attempt at recovery of a pressure cabin. *Results:* Orbit achieved (P = 188.5 mi; A = 228.7 mi; I = 64.9°; T = 91.1 min; speed on burnout of last stage = 17,300 m.p.h.). Owing to faulty attitude of satellite, the retro-rockets took the capsule into a new orbit (P = 191 mi; A = 429 mi; T = 94.25 min), instead of bringing it back to earth. Spoken messages stored on tape and received on earth.
MIDAS II **(USA)** W_t = 5,000 lb	24 May 1960 40 months Cape Canaveral	Two-stage Atlas-Agena W_L = 260,000 lb	*Shape:* Cylindrical; diameter 5 ft, height 22 ft. *Equipment:* Infra-red, telemetering and data transmission equipment. *Transmitters:* not known. *Power supply:* Chemical batteries.	*Objectives:* Testing of a system to detect missile launchings with the aid of infra-red sensors. *Results:* Orbit achieved (P = 292 mi; A = 322 mi; I = 33°; T = 94.3 min). Equipment for transmitting data from infra-red sensors failed two days after launching.
TRANSIT IIA + NRL SATELLITE **(USA)** W_p Transit IIA = 223 lb W_p NRL = 42 lb	22 Jun 1960 50 years Cape Canaveral	Two-stage Thor-Able Star W_L = 105,000 lb	**Transit IIA** *Shape:* Spherical with rings for solar cells; of plastic; diameter 36 in. *Equipment:* Two ultra-stable oscillators; infra-red sensors to detect satellite rotation; electronic clock as time standard; measuring instruments; receiver (Canadian). *Transmitters:* Four, frequencies 54, 324, 162 and 216 Mc/s; spiral ribbon antenna. *Power supply:* Solar cells and nickel-cadmium batteries. **NRL Satellite** *Shape:* Spherical; diameter 20 in. *Equipment:* Measuring instruments. *Transmitter:* One transmitter on 108 Mc/s; four whip antennas. *Power supply:* Solar cells and nickel-cadmium batteries.	**Transit IIA** *Objectives:* Testing the value of satellites as navigation aids for aircraft and ships; improving accuracy of geodetic measurements; provision of time standard; measurement of galactic noise. **NRL Satellite** *Objectives:* Measuring solar radiation (Lyman-Alpha and X-rays). *Results:* Orbit achieved (P = 389 mi; A = 665 mi; I = 66.7°; T = 101.7 min). Each satellite is separately following the same trajectory; both are transmitting data.

Name Total orbit weight (W_t) Payload weight (W_p)	Launching date Lifetime Launch point	Booster Launching weight (W_L)	Payload	Objectives and results P = perigee, A = apogee I = inclination, T = orbital period
DISCOVERER XIII (USA) W_t = 1,700 lb W_p = 300 lb	10 Aug 1960 to 11 Aug 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* As Discoverer V; instrumentation capsule diameter 33 in., length 27 in. *Equipment:* As Discoverer V, plus telemetering equipment to determine the reasons for re-entry errors in earlier tests; number of telemetry check points increased by almost 400%. *Transmitters:* / *Power supply:* As Discoverer V	*Objectives:* As Discoverer V, plus testing of new systems, equipment, components, materials and construction techniques. *Results:* Orbit achieved (P = 161 mi; A = 436 mi; I = 82° 51'; T = 94.1 min; speed on reaching orbit 17,614 m.p.h.); capsule ejected and recovered from Pacific.
ECHO I (USA) W_p = 166 lb	12 Aug 1960 unlimited Cape Canaveral	Three-stage Thor-Delta W_L = 112,000 lb	*Shape:* Spherical; balloon of Mylar plastic with aluminium coating; diameter inflated 100 ft; balloon container spherical, diameter 26.5 in., of magnesium. *Equipment:* None. *Transmitters:* On balloon, two beacons for tracking; diameter 10 in., thickness ⅜ in., weight 11 oz; 10 mW; frequency 107.94 Mc/s. In third stage, one beacon for telemetering. 60 mW; frequency 108.06 Mc/s. *Power supply:* On balloon, 70 solar cells and five nickel-cadmium batteries per beacon. In third stage, mercury batteries.	*Objectives:* Investigation of the feasibility of world-wide communication satellites. Aluminium coating designed to reflect 98% of radio waves up to a frequency of 20,000 Mc/s. *Results:* Orbit achieved (P = 945 mi; A = 1,049 mi; I = 47.2°; T = 118.3 min; speed at P = 15,973 m.p.h., at A = 15,643 m.p.h.). Voice communications carried out, e.g., between Holmdel, New Jersey, and Goldstone, California.
DISCOVERER XIV (USA) W_t = 1,700 lb W_p = 300 lb	18 Aug 1960 to 19 Aug 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* as Discoverer XIII. *Equipment:* As Discoverer XIII, plus additional equipment weighing 10 lb, including doppler beacon and external lights. *Transmitters:* As Discoverer XIII. *Power supply:* As Discoverer XIII.	*Objectives:* As Discoverer XIII; also measurements within Transit programme. *Results:* Orbit achieved (P = 187 mi; A = 502 mi; I = 79.6°; T = 94.5 min). Instrument capsule captured by a Fairchild C-119 in flight, at an altitude of 8,000 ft, 360 mi southwest of Honolulu.
SPUTNIK V (USSR) W_p = 10,120 lb	19 Aug 1960 to 20 Aug 1960 Aralsk (?)	Not known, probably multi-stage rocket of up to 1,000,000 lb thrust	*Shape:* In two parts; pressure capsule conical with rounded end. *Equipment:* Capsule containing two dogs, two rats, forty mice, flies, plants, fungi, microscopic water plants, seeds, photo emulsions; television camera for observation of animals; braking device. *Transmitters:* Number not known; frequency 19.995 Mc/s. *Power supply:* Not known.	*Objectives:* Testing of pressure capsule and recovery equipment; light measurements and investigation of heavy nuclei in the primary cosmic radiation, ultra-violet radiation from the sun and radiation inside pressure capsule. *Results:* Orbit achieved (P = 190 mi; A = 211 mi; I = 64° 57'; T = 90.72 min); capsule and carrier stage recovered after 18th orbit and 437,500 mi travel; landing occurred some 6 mi from scheduled point.
DISCOVERER XV (USA) W_t = 1,700 lb W_p = 300 lb	13 Sep 1960 to 14 Sep 1960 Vandenberg AFB	Two-stage Thor-Agena W_L = 108,500 lb	*Shape:* / *Equipment:* / *Transmitters:* / *Power supply:* As Discoverer XIII	*Objectives:* As Discoverer XIII. *Results:* Orbit achieved, data not known. Instrument capsule sighted in Pacific after re-entry, some 200 mi N. of Christmas Island (935 mi from scheduled impact area); recovery attempts unsuccessful.
COURIER IB (USA) W_p = 500 lb	4 Oct 1960 Several years Cape Canaveral	Two-stage Thor-Able Star W_L = 105,000 lb	*Shape:* Spherical; diameter 51 in. *Equipment:* Five tape recorders for data storage, daily capacity 3.4 million words. *Transmitters:* VHF and microwave transmitters, VHF beacon. *Power supply:* 19,152 solar cells, plus nickel-cadmium batteries (12 Ah, 28 V).	*Objectives:* Testing of feasibility of satellites for a global military communications network, to receive and store messages for later retransmission on command. *Results:* Orbit achieved (P = 500 mi; A = 730 mi); two ground stations for transmission and reception: Fort Monmouth, New Jersey, and Puerto Rico.

Vandenberg AFB, California, by *Thor-Agena*. The satellites did not go into orbit, as the booster vehicle in one case was damaged during launch, in another deviated from course and in the third failed to achieve the required burnout speed.

The interior of the unsuccessful *Pioneer VI* moon satellite. Instruments and radio equipment are grouped around the fuel tank.

Midas I: left Cape Canaveral on February 26th 1960 aboard an *Atlas-Agena* and was designed to trace ballistic missile firings with the aid of infra-red sensors. The second stage is believed to have failed to separate from the first.

Echo (no number): launched on May 13th, 1960 by a *Thor-Delta*. Second stage attitude control failed, and the third stage received no ignition signal from the ground.

Courier IA: fired on August 18th, 1960 by a *Thor-Able Star;* intended to test the feasibility of a global military communications system. The booster rocket exploded two and a half minutes after launch.

Pioneer VI was launched from Cape Canaveral by a three-stage *Atlas-Able* on September 25th, 1960; second stage, however, did not function correctly. This satellite was scheduled to circuit the moon for measurement purposes.

*

So much for the present survey. Competition in space is likely to get still more fierce in the years to come . . . and still more costly. The next survey may well report on the first return of a man from space. Let us hope, finally, that despite its enticing military aspects, astronautics will be used primarily to make a better world for all. ←→

Full-scale model of the *Courier IB*.

Grumman Mohawk... The Army's Flying Scout

It is in no way an easy task to lay down technical specifications for an ideal Army support aircraft to meet the requirements of modern land warfare. For one thing, forces must be armed for atomic war, while at the same time being prepared for conventional war. This means that army units must be widely dispersed, yet capable of rapid concentration; geared on the one hand to a wide-ranging war of movement, and on the other to more or less "static" operations. The army's air units at any rate must be designed for both forms of combat.

Secondly, there is the thorny problem of drawing the dividing line between army and air force responsibilities. In recent years, however, the NATO countries appear to have found a solution which satisfies both sides. This specifies roughly that wide-area reconnaissance, air defence of the combat zone, air support for the land battle and large-scale transport should be left to the air force, while liaison and ambulance flights in the combat zone, the transport of assault troops, and in particular surveillance of the battlefield, target spotting and artillery observation are typical army aviation responsibilities.* Following this idea, the United States and Canada have already acquired a substantial number of DHC *Beaver* and *Caribou* tactical transports and a fleet of helicopters for Army needs, while their European allies are using such aircraft as the Max Holste *Broussard,* Scottish Aviation *Pioneer,* Dornier Do 27 and various helicopters. For surveillance, target spotting and artillery observation, light aircraft have been chosen—*faute de mieux* (Piper, Cessna, Beach, Auster, Nord Aviation, etc.); these, for example, are included to the respectable number of some two dozen in the inventory of each of the U.S. Army Pentomic divisions.

What therefore are the requirements which must be met by a modern Army cooperation aircraft for reconnaissance and support duties? As its primary tasks are to carry out visual and photographic reconnaissance of the combat area and direct the fire of gun and rocket batteries, it must be able to operate from small fields and unprepared surfaces as close to the front line as possible. Constant up-to-date information on the development of the combat situation is of vital importance to the local commander on the ground, and the excessive delays which would occur if aircraft had to waste valuable time in flying from the base to the area of operations cannot be accepted. Similarly, it is essential that the passage of information from the reconnaissance unit to the ground commander should be as rapid as possible. To meet these needs, an aircraft must have at least STOL qualities, though the ideal would obviously be a rugged, foolproof VTOL model.

In addition, the army reconnaissance aircraft is expected to survive the operations on and above the battlefield. On the ground, therefore, it must be easy to camouflage, and in the air must have superior

* Cf. General L. M. Chassin: "What Kind of Aviation does the Army Need?" in *Interavia* No. 7, 1958, p. 687 et seq.

Grumman *Mohawk* with SLAR side-looking airborne radar underneath the fuselage. The SLAR scans the terrain to either side of the flight path and displays the echoes on screens, where they are photographed by an automatic film camera.

manoeuvrability to enable it to evade enemy fighters, for example by flying tight turns or by keeping low and making use of the cover provided by broken ground. It must have a crew of two, since a single pilot cannot be expected to concentrate at one and the same time on flying low, keeping a constant watch against attack and spotting significant but often inconspicuous details in the terrain and the combat situation. Finally, the army aircraft must be designed for ease of maintenance in the operational theatre, using simple facilities and a minimum of technicians.

On the other hand, an aircraft of this category must not be either *too* small or *too* light, otherwise its operational value will be limited. At least two engines would appear to be mandatory, to reduce vulnerability to fire from ground weapons. Furthermore, the crew must be in a position to attack targets of opportunity, such as vehicles, as soon as they are spotted, using missiles, rockets or napalm bombs. If additional support has to be called up, such targets may well escape undamaged. Last but not least, the wide dispersion tactics practised today by both friend and foe greatly increase demands on aircraft endurance, normal radius of action and ferry range, which means that a considerable quantity of fuel must be carried either inside the aircraft itself or in auxiliary tanks underneath the wings.

These are some of the considerations which led *Grumman Aircraft Engineering Corporation*, of Bethpage, Long Island, N.Y., to produce a revolutionary new design for a twin-engine, two-seat STOL aircraft, the *Mohawk*. No fewer than 86 of these aircraft (9 of the YAO prototypes and 77 AO-1s) have been ordered for the U. S. Army and U.S. Marine Corps. A company which for decades has worked almost exclusively on Navy requirements has thus not only extended the range of its customers, but at the same time inaugurated a new era in Army air operations. The first prototype (YAO-1) of the *Mohawk* made its maiden flight on April 13th, 1959. The flight test programme has meanwhile been practically completed, and quantity production has begun.

Structural details

The *Mohawk* is an all-metal mid-wing monoplane with a span of 42 feet and a maximum wing loading of only 30.5 lb/sq. ft. Power is supplied by two Lycoming T53-L3 turboprops of 1,005 e. h. p. each on take-off (960 s. h. p. plus 110 lb residual thrust), which drive continuously variable three-blade propellers of relatively large diameter (roughly 10.5 ft). Thanks to the extremely small propeller load-

A production model aircraft (AO-1AF) takes off from a semi-prepared airfield. Slats, Fowler flaps, low power loading and wing loading and large propeller disc ensure outstanding short take-off capabilities.

Main data for the Grumman AO-1 Mohawk

Dimensions		Weights	
Span	42 ft	Weight equipped	7,770 lb
Length	41 ft	Useful load	2,320 lb
Height	12 ft 8 in.	Gross weight	10,090 lb
Wing area	330 sq.ft.	Max. wing loading	30.5 lb/sq.ft.

Powerplant	
Two Lycoming T53-L3 turboprops	
Large-diameter three-blade v.p. propellers	
Take-off power (25,240 r.p.m.)	1,005 e.h.p.
Continuous power (24,430 r.p.m.)	865 e.h.p.
Propeller speed (take-off)	1,700 r.p.m.
Power loading (take-off)	5 lb/e.h.p.

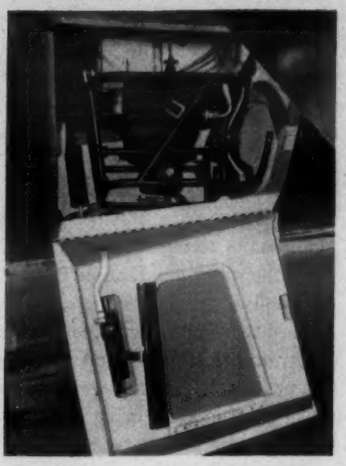
Performance	
Max. speed at 5,000 ft	315 m.p.h.
Stalling speed, with flaps	64 m.p.h.
Initial rate of climb, two engines	3,000 ft/min
Initial rate of climb, one engine	1,050 ft/min
Service ceiling	32,500 ft
Total endurance at 230 m.p.h. and 5,000 ft	2 hours
Total endurance with auxiliary tanks*	7 hours
Take-off distance to 50 ft altitude	660 ft
Landing distance from 50 ft	780 ft
Ferry range with auxiliary tanks*	1,670 miles

* two tanks, capacity 150 U.S. gallons each.

The *Mohawk's* main instrument panel is inclined 15 degrees forwards: dual sets of blind flying instruments; several voice radio sets; radio compass; oxygen equipment. The engine throttles are, as usual, positioned between the two seats.

As it has not been possible to give the crew defensive weapons, two Martin-Baker MB-A5 ejection seats are fitted. If necessary, the crew can be shot through the roof hatch.

The radio and electronic bay, easily accessible from the ground, lies in front of the air brakes (maximum deflection angle 60 degrees). Photo shows a mock-up of the aircraft.



Further forward, in the fuselage belly, are the cameras.

Though normally fitted with Goodyear low-pressure tyres, the *Mohawk's* undercarriage can also be equipped with skids which, when retracted, lie flush against the underside of the aircraft and thus produce no appreciable drag.

ing and the low wing loading, the aircraft can take off in a very short distance—roughly 660 ft to clear a 50-ft obstruction. Low-pressure tyres on the undercarriage (Goodyear) permit of take-off from grass fields and forest clearings. The requirement for good short take-off capabilities on makeshift airfields is therefore met.

The aircraft has top speeds of more than 315 m. p. h. Nevertheless, thanks to large-area Fowler flaps and leading edge slats extending over the full span, its stalling speed is unusually low, namely 64 m. p. h., which gives a speed range of 1 : 5. During approach to landing the air brakes in the fuselage sides can be deflected by 60 degrees, so that total landing distance from 50 ft is under 780 ft. To improve directional stability with one engine out and to avoid powered controls, the aircraft is fitted with three fins . . . though originally it had only one. The outboard fins act as end plates for the low-set elevator unit and thus improve the latter's efficiency at low speeds with flaps in operation.

Pilot and observer sit side by side in a roomy cabin with bubble-type side panels giving a good downward view for both crew members. Forward vision is also good, thanks to the extra-short fuselage nose, and the crew can keep a look-out upwards—though not rearwards—through the glass canopy. As it has not been possible to provide the

Special attention has been given in the design of the *Mohawk* to ease of maintenance in the operations area: port and starboard engines, main undercarriage legs, outboard fins and elevators are interchangeable, which simplifies the provision of replacements. Only hand tools are needed to exchange the components which experience suggests will require more frequent replacement.

crew with defensive weapons, the aircraft is at least fitted with two Martin-Baker MB-A5 ejection seats, to ensure rapid escape from any altitude in an emergency. The crew need not even jettison the cabin canopy first, but can be projected through the roof hatch.

The *Mohawk's* equipment includes—in addition to removable equipment and voice radio—one or more reconnaissance cameras mounted vertically or obliquely in the underside of the fuselage, plus guided missiles or containers for unguided rockets on under-wing pylons for anti-tank operations. The rockets can be replaced by napalm bombs or two auxiliary fuel tanks with a capacity of 150 U. S. gallons each. For night operations, two flare containers (52 flares each) can be mounted on top of the wing roots. The flares are ejected upwards. Finally, in view of the steadily growing importance of radar reconnaissance, a long tubular container can be carried under the forward portion of the fuselage—slightly to starboard—for the SLAR (side-looking airborne radar). This equipment scans the ground to either side of the flight path, displays the results on screens and then photographs the image with an automatic film camera (4 × 5 in. cut film or 70-mm film strip). When time presses, the film can be developed immediately by an inflight processer, so that the observer can interpret the photographs a few minutes after exposure (as a general rule, however, interpretation will probably be left to the staff back at base). The outcome is a radar map of the terrain flown over. There is no need to add that the *Mohawk* will also be equipped with radio compass (and possibly a TACAN station), full blind flying instrumentation, and oxygen system.

Other features: the two main wheels are retracted outwards to lie underneath the engine nacelles, which results in a relatively narrow track width. The robust shock absorber undercarriage legs have a very long travel and can cope with a maximum vertical velocity of 17 ft/sec. Special attention has been given to ease of maintenance. Port and starboard engines are interchangeable, which simplifies the supply of replacements, and each engine can be removed or installed by two men in thirty minutes, using a special davit developed by Grumman. The main undercarriage legs, horizontal stabilizer halves, elevators and outboard fins and rudders are also interchangeable. All access panels to components and accessories are positioned so as to be accessible to a man standing on the ground. Finally, all components

The excellent manoeuvrability of the *Mohawk* enables it to fly very tight turns near the ground, thus making optimum use of ground cover.

requiring frequent replacement are designed in such a way that no cutting, fitting or drilling is needed. Damaged wing or tail panels are replaced *en bloc*.

The introduction of the *Mohawk* into U. S. Army aviation will thus represent a considerable step forward in the techniques of battlefield reconnaissance: its STOL qualities will enable it to use forward airfields which can be easily camouflaged. For campaigns of movement, its greatly increased range and speed will permit it to maintain its position with the leading troops, while working from airfields that have been left considerable distances behind the front line. And finally but not least important, it can operate in practically any weather and is well equipped to deal with targets of opportunity.

It has often been said that "reconnaissance wins wars," and it is obvious that the best informed commander always possesses the initiative. Armed with aircraft of the capability of the *Mohawk*, the reconnaissance forces will be well equipped to win and maintain that initiative. ◆◆

Each engine can be removed or installed by two men within 30 minutes, with the aid of a special davit developed by Grumman and a standard bomb hoist.

Manufacturing the *Mohawk* at the Grumman Bethpage plant, Long Island. So far a total of 86 aircraft have been ordered for the U. S. Army and U. S. Marine Corps.

Whither World Air Transport?

Marginal Notes on the 16th IATA Annual General Meeting in Copenhagen

Say it with music . . . The opening of the 16th IATA Annual General Meeting at the Falkoner Centret, Copenhagen. This year the platform was occupied not by the IATA Executive Committee, but by the Royal Danish Symphony Orchestra.

After 40 years the Annual General Meeting of the International Air Transport Association has returned to IATA's cradle. For it was in Copenhagen that the International Air Traffic Association held its first Annual General Meeting in 1920, a year after its foundation, and that the six founder companies of the original IATA agreed on their Articles of Association. Who at that time could have foreseen the development which was to take place during the next four decades? And who would have believed that air transport would reach out across the continents and oceans to become an economic and political factor of the first magnitude?

But despite all the transformations in its structure and technical equipment, the overall problem of air transport remains the same. Travel by air must still be made as economical and comfortable as possible, so as to open it up to ever wider categories of passengers. But the number of individual problems has grown with the rapidly increasing volume of this branch of transport. And the impartial observer is surprised that IATA can continue to regulate the powerful machinery of world air transport, and that it can more or less meet the wishes of its 89 members while taking account of the diametrically opposed demands of individual companies.

At the opening session of the 16th Annual General Meeting, attended by King Frederik and Queen Ingrid of Denmark, speakers voiced clear and unambiguous pleas for the liberalization of world air transport. The Danish Prime Minister Viggo Kampmann, the outgoing IATA President Seijiro Yanagita (Japan Air Lines), and the new President, Åke Rusck (SAS), strongly emphasized the need for an "open skies" policy and pressed for greater liberality in granting landing rights. The current United States air transport negotiations with the Japanese Government and with Norway, Sweden and Denmark provided a highly topical background for these demands. Although bilateral negotiations for landing rights and air routes are not the province of IATA, such agreements invariably have repercussions on the tariff structures of IATA members. Should the protectionist trends in world air transport become intensified, certain zones will find themselves in dangerous isolation. And the main aim of IATA, as set forth in its Articles of Association — to promote safe, regular and economical air transport for the benefit of the peoples of the world — will remain a hollow mockery.

As expected, the worldwide introduction of jet aircraft and the resulting sudden increase in seat capacity provided the main topic of discussion for the more than 200 delegates who met between September 12th and 16th at the Falkoner Centret in the heart of Copenhagen at the invitation of the host airline, SAS. But questions of basic importance regarding the internal organization of IATA were also on the agenda and were the subject of discussions even during intervals between sessions and in private conversations.

Since the reorganization of the International Air Transport Association in 1946, power to bind and loose has been concentrated in the hands of the eighteen-member Executive Committee, which makes final decisions and determines the structure of the agreements and conventions concluded within IATA. For years now, the smaller companies have been pressing for a voice in the Executive Committee to enable them to break free from the oppressive monopoly of the larger carriers. But this year too, the trial of strength between great and small ended in favour of the former, for the Committee, which consists for the most part of representatives of the leading air transport companies, elects its new members itself. As was to be expected, the seats vacated this year by former BOAC Chairman Sir Gerard d'Erlanger and I. A. Aler, President of KLM,

Guests of honour at the opening session: King Frederik and Queen Ingrid of Denmark.

Restrained optimism was displayed by the speakers: Director General Sir William Hildred (left) and Åke Rusck, President for 1960/61.

have been reoccupied by representatives of the same companies. The balance of power in the Executive Committee remains unchanged.

The air transport giants claim that their presence on the Executive Committee is justified because —on the basis of their impressive operating statistics—they pay considerably higher membership fees than the smaller companies. But a democratization of the election mechanism for this committee and other permanent IATA bodies seems essential if certain companies are not to leave the organization in coming years. What is more, the Executive Committee also provides over 90 percent of the members of the Traffic Advisory Committee, so that this important body likewise represents the opinion of the Executive Committee in vital matters. The Traffic Advisory Committee recently recommended separate voting on passenger and freight tariffs with the aim of excluding pure freight operators from decisions on passenger fares, a recommendation which understandably met with fierce opposition from the freight operators. Even in the first plenary session, the resignation of Traffic Director John Brancker, engineered by Sir William Hildred, the Director General, led to a lively debate, which centred not only on the person of the undoubtedly capable Traffic Director, but also on the relationship between the IATA Directorate and the IATA Traffic Conferences. For the time being Sir William himself will take over Brancker's duties, until a special committee has "reviewed the administrative machinery of Traffic Conferences and their relations with the Executive Committee."

The tug-of-war inside IATA is, of course, primarily concerned with the fare structure and in particular with the wish of certain financially powerful companies to reduce fares still further. In this connection, attention should again be drawn to the introduction of the cut-rate 17 day winter excursion fares across the North Atlantic on October 1st. Although all the major North Atlantic operators are organizing vast sales campaigns to advertise the new fares, the prospects and expectations of individual companies differ widely. An *Interavia* inquiry gives the following picture.

Pan American World Airways is optimistic and says that economy class advance bookings for the first week of October were double last year's figures (2,230 against 1,085), but advance bookings for later weeks tapered off to last year's figures.

Trans World Airlines is even more optimistic and estimates that some 50,000 passengers will use the new excursion fare on the North Atlantic between October and December this year. October eastbound economy class forward bookings were up 133 percent on last year, and November bookings were up over 300 percent.

Trans Canada Airlines, one of the main advocates of the new rates at the IATA Traffic Conference in Paris earlier this year, says that the excursion fares were largely responsible for a 150 percent increase in advance bookings for October. Figures for the following five months are also well up on last year.

BOAC says that the announcement of the new excursion fare has brought a significant increase in overall advance bookings. BOAC forward bookings from Canada are 130 percent up on last year's figures.

Air France strikes a pessimistic note and sees little prospects for a significant increase in North Atlantic traffic; like several other carriers, it points out that the passengers utilizing the new rates will be gained at the expense of the normal economy class. Air France comments that winter is in any case hardly a suitable time for Europeans to take holidays in the United States.

Swissair says that it is too early yet to assess public reaction, but that advance bookings show a definite increase over last year. The greatest response is from the travel industry, which has readily adapted the new rate to the promotion of group travel and study tours. The carrier believes that, given time, the excursion fare will help to open up new traffic sources.

Lufthansa is facing its first winter season with jets and can make no comparison with last year. The carrier believes that the question of a possible increase in traffic is wide open.

Sabena says that bookings are higher than last year, but that it is impossible to ascertain whether this is the result of the introduction of new rates or solely due to the normal increase in traffic. Sabena feels that a 17 day excursion period is too short, and that this should be increased to at least 30 days.

SAS also reports an increase in advance bookings and expects that the new rates will be exploited by commercial houses to intensify business contacts. The carrier feels that businessmen may now take assistants with them and that trainees and junior executives may be sent on study trips.

KLM expects a considerable increase in North Atlantic traffic, but at some cost to normal economy class traffic. KLM found that there had been no great rush for advance bookings in view of the available capacity.

In the opinion of the Director General, fare reductions in the past have made a vital contribution to the development of international air transport, and IATA should therefore continue to follow this policy. More important than further increases in speed was the reduction of fares, said Hildred, alluding to the increasing talk of supersonic transport.

But there are only three possible ways of lowering air fares: a further reduction in the airlines' already slim profit margins (where such do, in fact, exist), government subsidies, and finally, the reduction of direct operating costs for the services offered. But few appreciable savings can be made here, apart from lowering fuel prices and introducing modern navigation aids to enable the shortest possible distances to be flown between landing points. For all IATA members, fuel costs account on an average for 15 to 16 percent of total expenditure, but will rise to 30 percent after all the jet aircraft at present on order have been placed in service. Fuel costs could be appreciably lowered only by the issue of new fuel specifications (same energy content at lower cost), improved fuel metering, cheaper refuelling methods and, last but not least, reductions in the taxes charged by various States. In view of the general upward trend of costs, however, reduced fares seem hardly justifiable in the case of many companies. Only financially strong carriers can afford further reductions on certain routes without first obtaining precise information on the passenger volume to be expected.

Airline heads as the guests of the Danish Government at the Hôtel d'Angleterre.

On the other hand, general improvements which will have a favourable effect on airline costing plans can be made in ground organization, and the formation of a Ground Handling Advisory Group, announced by the Executive Committee, was universally welcomed. The Group's main task will be to speed up the processing of passengers and cargo through main airports and town terminals, reducing the time taken from the moment of check-in at town terminals until actual aircraft take-off. The Group will be made up of experts from twelve international carriers in Europe, North America, Australia and the Far East. Assuming full support from all airport authorities, much valuable work should be done in this field.

Despite the difficulties mentioned above, world air transport has some cause to congratulate

Functional modern design — the Falkoner Centret with the Tre Falke Hotel, the scene of the International Air Transport Association's 16th AGM.

itself on its performance for last year. As the preliminary ICAO estimates for 1959 show, operating revenues have increased by about 11.8 percent to $4,610 million; operating expenses have risen 8.8 percent to $4,470 million, leaving an estimated operating profit of about $140 million, or 3.1 percent. Small as this is, it represents a considerable improvement over the 1958 figure of under 0.5 percent.

As for operating statistics, the IATA companies reported passenger-kilometres up by 14 percent, freight tonne-kilometres up by 16 percent and mail tonne-kilometres up by 11 percent. For the current year, it is predicted that the scheduled operators will carry over 100 million passengers, compared with 31 million in 1950. Across the North Atlantic the rise has been particularly gratifying: the passenger volume for 1959 increased by 19.2 percent over the previous year, and the freight volume by 45.5 percent.

At the end of 1959 the total operating fleet of IATA members stood at 3,479 aircraft. A total 246 older aircraft were retired during the year, and 126 new jets, 150 new turboprops and 7 new helicopters placed in service. As the industry re-equipped with jets (it would have about 600 by the end of 1962), there would be a surplus of between 1,200 and 1,800 piston-engine aircraft by the end of 1961. Although some could be put into cargo or charter operation services, the disposal of the fleet remained a serious problem for the airlines.

Pilgrimage into the past: IATA delegates at Frederiksborg Castle.

The jet aircraft, on the other hand, had come through their early ordeals with flying colours and had, in the words of Sir William Hildred, proved themselves "magnificent instruments for the mass production of air transport." According to IATA statistics, the average daily utilization of jets was already 7 hours, and in some cases as much as 8 or 10 hours, this despite certain initial difficulties.

Sir William urged the airlines to intensify their advertising campaigns for air freight, as the freight capacity offered is still considerably in excess of demand. By mid-1961 at least 60 pure freight aircraft should be in operation, and by the end of that year the freight capacity offered by the IATA members alone will have doubled. What is more, although about 18 percent of the scheduled tonne-kilometres performed throughout the world fall to the credit of air freight, the earnings which it has brought in amount to only 10 percent of total earnings. Only the scheduled transport at greatly reduced rates of bulk loads weighing at least 50 tonnes will inject life into the freight business.

The introduction of jet airliners on the most important air routes also occupied the IATA Technical Committee, whose annual report comments as follows:

On most air routes safety of operation has been adequate, but much remains to be done to improve the reliability and economy of high-speed, high-altitude flying. Of particular urgency are the extension of telecommunications facilities and their technical improvement in certain regions of the globe, and the improvement of maintenance and ground handling. The Committee made a systematic investigation of doppler radar navigation systems at present on the market, proposed modifications to the ATC regulations for jet airliners, and discussed all-weather landing systems. The Production Planning and Control Group has issued the first instalment of a Handbook on Production Planning and Control, which deals with all aspects of planning, equipment procurement and production performance analysis.

In spring, 1961, the Technical Committee will hold an international seminar, to which airlines, manufacturers, research institutes and authorities will be invited. Here the views of individual airlines on basic requirements for supersonic airliners (range, speed, size of aircraft) should crystallize in such a way as to form a basis for the 1961 Technical Conference. The conference, which opens in Montreal on April 17th, 1961, will be devoted primarily to supersonic transport. This, said Sir William Hildred laconically, was "a prospect we must face within the next decade ... whether we like it or not." At present, IATA would endeavour to warn all companies of the dangers of over-hasty decisions to place supersonic aircraft in service. In this connection Sir William said: "I can imagine no unhappier issue than the production of a supersonic aircraft which the airlines cannot operate with any hope of economic success and which will therefore be a disaster for the manufacturers ... I hope ... that no one will be panicked into producing or accepting a supersonic aircraft before we have had a chance to digest the jets and equip ourselves for the even more demanding transition ahead."

In passing, mention should be made of a problem which is becoming ever more pressing. Almost unnoticed by the general public, the Association urged its members to energetically oppose increases in dues for the use of airports and air traffic control facilities. The President of the IATA Financial Committee, Harald Bernström, recommended that carriers should settle such questions direct with the governments of the countries concerned, as collective negotiation at IATA level was impossible.

With the approval of the 1961 budget and the establishment of membership dues, the 16th Annual General Meeting closed in the same sober spirit in which it had been conducted for the preceding four days. The budget provides for revenue of $1,262,500 and expenditure of $1,583,300, anticipating an appropriation from surplus of $320,800. Dues for associate members are fixed at $500 per annum. The assessment for active members comprises a fixed minimum levy of $1,000 and a variable levy based on the revenue tonne-kilometres performed during the period January 1st to December 31st, 1959 ($0.737 per 1,000 on the first 5 million, $0.641 per 1,000 on the next 15 million, and $0.296 per 1,000 over 25 million).

Sir Matthew Slattery, present Chairman of BOAC, was elected to the Executive Committee to replace Sir Gerard d'Erlanger, who has resigned from the company, and KLM President I. A. Aler was replaced by KLM Deputy President E. H. van der Beugel.

SAS President Åke Rusck presided at this smoothly organized 16th Annual General Meeting with unobtrusive efficiency, and modestly took leave of his international guests to take over the presidency of IATA for the coming year in addition to his many responsibilities as head of Scandinavian air transport. He will be succeeded as IATA President in 1961/62 by Sir Hudson Fysh, Chairman of the Board of Qantas Empire Airways, who has invited members to the 17th Annual General Meeting in Sydney on October 23rd, 1961. The 18th Annual General Meeting will open in Dublin on October 10th, 1962, with Aer Lingus as host; the IATA President for 1962/63 will be J. F. Dempsey. In 1963 the Annual General Meeting will go to Vienna and in 1964 to Istanbul.

The path taken by the world's airlines in the coming years will be decisive for the future of air transport. A prologue by the Danish poet Piet Hein, composed specially for the IATA Annual General Meeting, gives a new twist to Hamlet's old saying with the warning: "Co-existence or no existence." ⟷

What's in the Air?

René Bigand, Chief Test Pilot to Générale Aéronautique Marcel Dassault, climbing out of the Mirage IV 01 *in which he broke the world speed record for a 1,000 km closed circuit, flying at an average speed of 1,820 km/h.*

MILITARY AFFAIRS

France and her NATO partners reached agreement at the end of September on the long-discussed question of a unified air defence system for Western Europe. The agreement covers the following main points:

1. Complete unification of French and Allied early warning radar systems (this applies only to the French early warning stations along the north-east frontier).
2. Unification of the French and Allied air forces in the forward area, comprising the German Federal Republic and the territory along the Franco-German frontier. All air forces stationed in this area will be placed under NATO command, although in the event of war the French units can be employed only on orders from the French command. French air forces stationed outside the forward area remain under national command, though joint exercises will be carried out with other NATO units.

The United Kingdom and the United States have drawn up a technical agreement on cooperative development of the *Sky Bolt* ALBM. The terms cover such matters as the participation of British technicians in the programme in the United States. Meanwhile, Douglas Aircraft spokesmen have stated that the *Sky Bolt* is scheduled to become operational and capable of quantity production for USAF B-52 and RAF *Vulcan* requirements by 1964. System configuration, missile mockups, aircraft and missile mockups and engine tests have already been completed.

The U.S. Air Force is expected to select a contractor in the near future to develop a new short take-off and landing fighter for Tactical Air Command. Eight companies (Boeing, Convair, Douglas, Lockheed, North American, Northrop, McDonnell and Republic) are believed to have submitted proposals to the Air Force against Specific Operational Requirement 183. It should be noted, however, that by "STOL" the Air Force means the ability to operate from 5,000 to 6,000-ft runways (about half the length of today's jet runways). Principal requirements are a top speed of Mach 2.3, a low-level speed of Mach 1.2, a combat cruise range of 1,500 miles and an unrefuelled ferry range sufficient to fly the longest island-to-island routes across the Pacific.

In two recent sessions, Congress voted the Air Force a total of $36 million to begin development of an advanced tactical fighter, and presumably this fund will be used to get the STOL programme going.

Plans for the modernization of MATS are now well advanced. Air Materiel Command is expected to place a first order for 16 Lockheed C-130Es in the very near future, a number which is to be increased to 50 over the next two years. This, however, represents merely an interim solution to the problem of providing MATS with strategic airlift capability, pending the availability of the turbofan transport to be developed especially for MATS under Specific Operational Requirement 182. A special board will meet towards the end of November to select the contractor to develop this aircraft. Requirements are 4,000 miles range, 25-ton cargo capacity, air-drop capability and a cargo deck of truckbed height for rapid loading.

AIR TRANSPORTATION

The International Civil Aviation Organization has assigned a team of experts in aeronautical communications, air traffic services and aeronautical meteorology to the Southeast Asia Region to provide on-the-spot help and advice to states in the area and to report on measures required to produce long-term improvements in existing facilities. The team will visit key points along the air routes to observe the layout and use of equipment, the day-by-day working methods and the difficulties being encountered.

Henrich Focke (left), a pioneer German aircraft builder and founder of Focke-Wulf Flugzeugbau AG, celebrated his 70th birthday on October 8th. Focke is at present engaged in building the three-seat Kolibri *for Carl F.W. Borgward GmbH. Dr. Ing. Hans Heyne (right), Chairman of the Board of Telefunken GmbH, was 60 years old on October 4th. Employed with Telefunken since 1950, he played an important part in the expansion of the firm during the post-war period.*

The scheduled air carriers of ICAO member States recorded 28 fatal accidents in 1959 (against 30 in 1958), in which 625 passengers (629) were killed; fatal accident rate per 100 million passenger-km was 0.66 (0.74).

IATA and the Transatlantic Passenger Steamship Conference have concluded an agreement under which Atlantic passengers can travel one way by air and the other by sea at a reduction of 10 percent of the round-trip fare, provided they travel during the slack period of sea transport. Baggage and cars are also eligible for the 10 percent reduction.

The International Transport Institute formed in New York at the end of August 1960 to engage in research and study of all forms of transportation, with particular reference to the requirements of under-developed countries, is headed by Herbert B. Dorau, of New York University, as Director, and Dr. Jacob Schenkman, an international transportation consultant, as Director of Research.

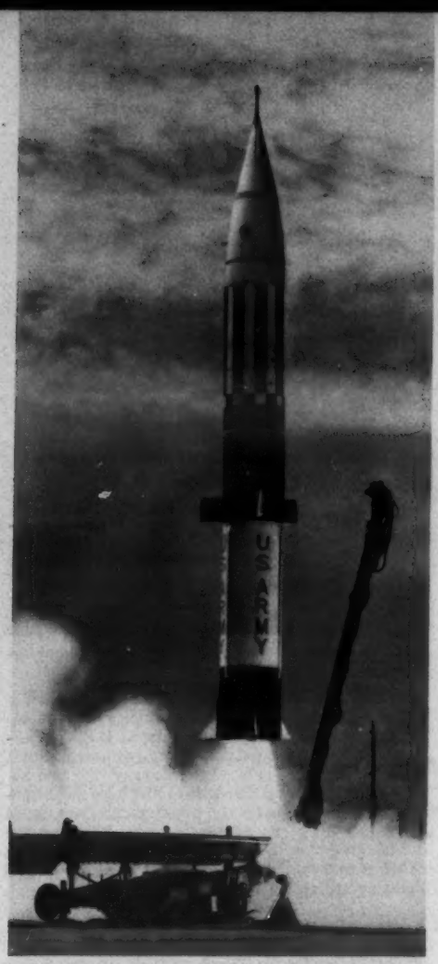
The U.S. Federal Aviation Agency has adopted the Royal Aircraft Establishment's visual glide path indicator as national standard for use at U.S. civil airports. The RAE system consists of two sets of lights mounted at either side of the runway, the first set installed 1,250 ft and the second 750 ft from the threshold. Red filters change the appearance of the lights depending upon the approach angle. When on the correct glide slope the pilot sees the near bars of light as white and the far bars as red; if he is too low all lights appear red, if too high as white.

INDUSTRY

Export orders for the French aviation industry during the first half of 1960 totalled 808,793,373 new francs ($161.8 million), compared with 45,000 million old francs ($90 million) for 1959. Orders for complete aircraft, helicopters and spares increased by 310 percent over the corresponding period in 1959, for engines and spares by 55 percent, for missiles by 100 percent, and for equipment by 80 percent. Contracts booked by Sud-Aviation for the *Caravelle* during the six-month period accounted for almost 45 percent of total export orders.

Eight leading U.S. airframe manufacturers have attended a technical briefing at the Air Force's Wright Air Development Center on a new Air Force programme which could lead to the development of a supersonic transport aircraft for both military and commercial use. The eight companies (Boeing, Convair, Douglas, Lockheed, McDonnell, North American, Northrop and Republic) were asked to submit preliminary ideas in a brief report, after which the Air Force would select four contractors to engage in a six-month study, possibly in conjunction with engine manufacturers. Based on the results, the Air Force

A version of the four-engine turboprop Antonov An-10 with modified fuselage rear is in operation with the Soviet Air Force—apparently in large numbers. The main difference between this and the passenger version is in the upswept fuselage rear (presumably with loading hatch and ramp); there is also a rear gunner's position, and the aircraft has a long fin running from the rudder along the top of the fuselage.



Launching of a Martin Pershing. *This two-stage solid-propellant rocket with a range of about 500 miles is to replace the* Redstone *surface-to-surface guided missile at the end of 1962. Thiokol supplies the powerplant, Bendix the guidance system.*

will then decide whether to order a full-scale design competition.

The Pentagon and NASA have established a joint Aeronautics and Astronautics Coordinating Board to continue the functions of the National Aeronautics and Space Council and the Civilian-Military Liaison Committee, which were abandoned earlier this year. The new Board, which has been meeting informally since July, will have NASA Deputy Administrator Hugh Dryden and Defense Research Director Herbert York as co-Chairmen. It will review planning by the Pentagon and NASA, coordinate activities of common interest, identify mutual problems and secure a steady exchange of information.

General Electric Company has received a $32.2 million USAF production contract for the J85-5 afterburner jet engine, with delivery scheduled for late 1961 and early 1962. Hitherto General Electric's Small Aircraft Engine Department has been manufacturing this engine only for the prototype T38, N-156F and Q-4B. The new contract is the largest ever received by the Department.

Chance Vought Aircraft Company has been awarded a U.S. Navy contract valued at $68 million for fiscal 1961 procurement of the F8U-2N all-weather interceptor. This brings total orders for the aircraft up to $162.6 million and provides for continued production up to December 1962.

Lockheed Aircraft A.G. is a new company registered in Geneva, with a capital of 250,000 Swiss francs ($58,000). Aims of the company are listed as sales, distribution, assembly and manufacture of aircraft and electronics systems, together with maintenance and repair. This is a Lockheed Aircraft International subsidiary, set up primarily to facilitate the exchange of technological information with West European companies.

AIRCRAFT, MISSILES AND POWERPLANTS

The new Rolls-Royce RB-168 military turbojet bears a close resemblance to the civil RB.163 and is presumably the unit proposed by Rolls-Royce for the Blackburn NA.39 strike aircraft. If approval for the use of the RB.168 in later NA.39s is given, it would have the dual effect of extending the NA.39's range by virtue of lower fuel consumption and also provide Rolls-Royce with valuable flight time running to back up the RB.163 programme for the DH.121.

The Breguet 940 experimental STOL aircraft was again turned over to crews of the Brétigny Flight Test Centre (CEV) on September 26th. On September 23rd the aircraft made a further series of demonstration flights at Villacoublay before representatives of the armed forces, civil aviation and Air France's postal service. At these demonstrations, the 940's landing roll was about 160 ft; it also showed its good handling qualities by making low-speed turns with a radius of less than 230 ft. The Breguet 940 has so far logged over 200 flight hours and made more than 650 take-offs and landings.

The first prototype Potez 840, powered by four Turboméca *Astazou* propeller turbines, will in a few weeks' time be assembled at Toulouse, where it will undergo static tests. The first flight is scheduled for the beginning of 1961. A second prototype is under construction at Argenteuil.

Nihon Airplane Manufacturing Co. (NAMCO) will begin production of 150 turboprop YS-11 transports under Japanese Government subsidy, beginning in fiscal 1963. The first prototype will be completed at the end of 1961, the second early in 1962, and the two aircraft will make test flights throughout 1963. Two further airframes will also be built for use in static tests. The first of the YS-11 transports is scheduled to go into operation on Japanese domestic routes in the second half of 1963.

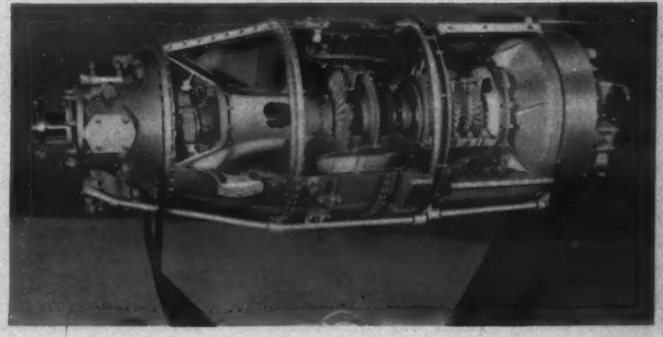
Scheibe Flugzeugbau GmbH, of Dachau, near Munich, has been making a series of modifications to its two-seat SF 23 *Sperling* with a view to improving performance and flight qualities. All versions of the SF 23 now have split flaps. Further improvements are in the exhaust, the undercarriage (which now has 6.00-6 wheels and, if required, shock absorbers), and the tail skid, which is designed for minimum maintenance. The engines of the three versions are as follows: 95 h.p. Continental C90 in the SF 23A/K1; 100 h.p. Continental 0-200 in the SF 23B; 115 h.p. Lycoming 0-235-C1 in the SF 23C.

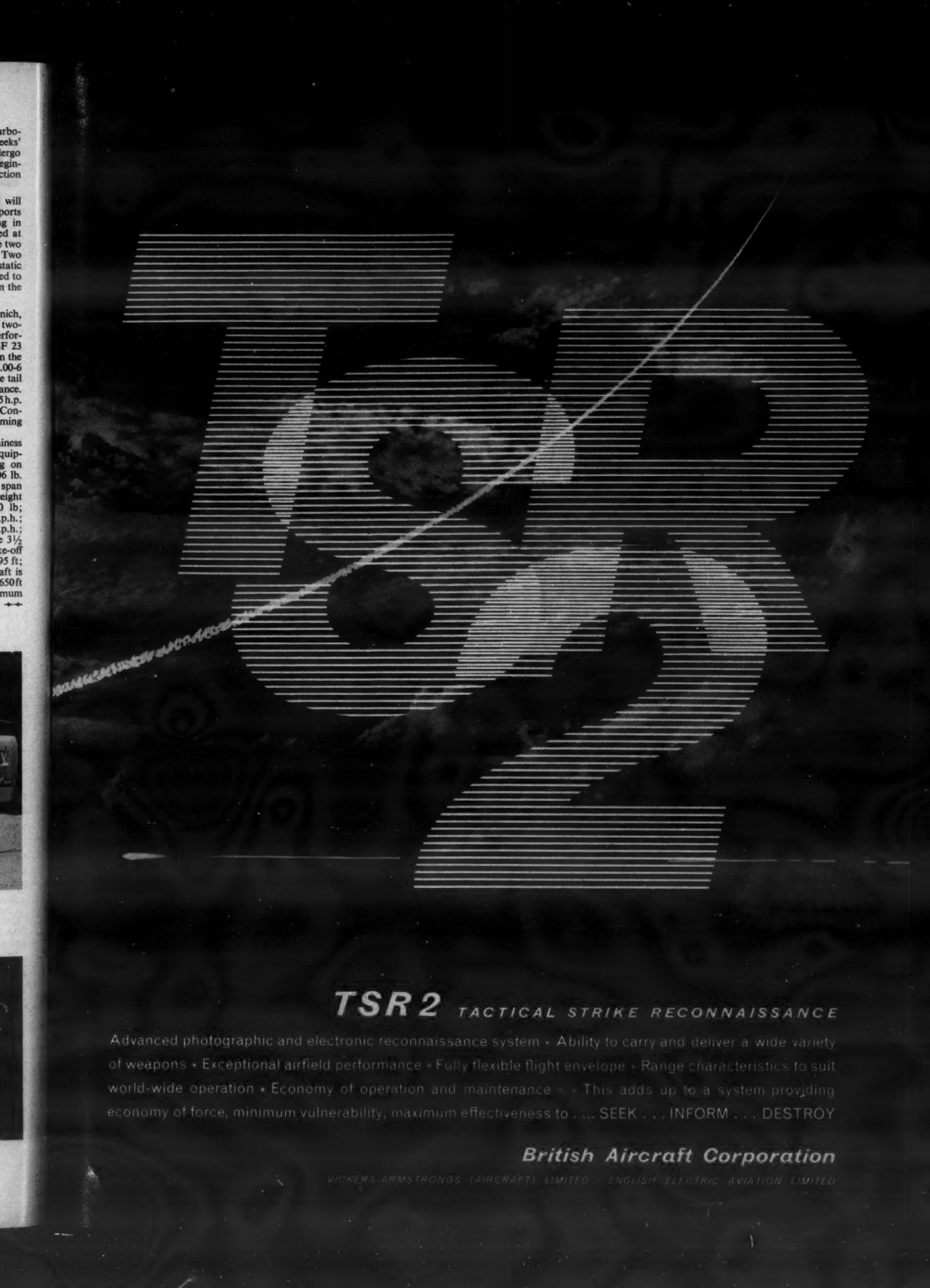
All three versions meet the American airworthiness specifications (CAR Utility Class). The weight equipped is between 1,010 and 1,060 lb, depending on engine type; the maximum all-up weight is 1,606 lb. The main data for the SF 23C are as follows: span 32.6 ft; length 20.4 ft; wing area 131.3 sq.ft.; weight equipped 1,060 lb; maximum useful load 550 lb; gross weight 1,606 lb; maximum speed 130 m.p.h.; cruising speed at 60 percent engine power 105 m.p.h.; stalling speed, flaps down, 43 m.p.h.; endurance 3½ hours; range 372 miles; take-off roll 560 ft; take-off distance over 50 ft screen 1,385 ft; landing roll 395 ft; initial rate of climb 770 ft/min; when the aircraft is used for towing sailplanes, the time to climb to 1,650 ft with a 900 lb sailplane is about 4 minutes; maximum weight for aerobatics 1,495 lb. ⟷

USAF Major Walter Hodgson (left) and Leonard LaVassar, Vertol Chief Test Pilot, standing before the Vertol 76 tilt-wing VTOL experimental aircraft. NASA is evaluating the aircraft for the U.S. Army at Langley Field.

◀ *Drawing of the* Mauler *anti-aircraft missile system under development at Convair. Designed for use against enemy short-range guided missiles and strike aircraft, the system can be mounted on light to medium-weight mobile launchers. The target acquisition radar, fire control system and launching mechanism can be operated by one man, even while the launcher is in motion.*

Sectioned model of the Canadian Pratt & Whitney Aircraft PT-6 (U.S. military designation T74) shaft or propeller turbine. The PT-6 is rated at 500 s.h.p. and weighs 250 lb.

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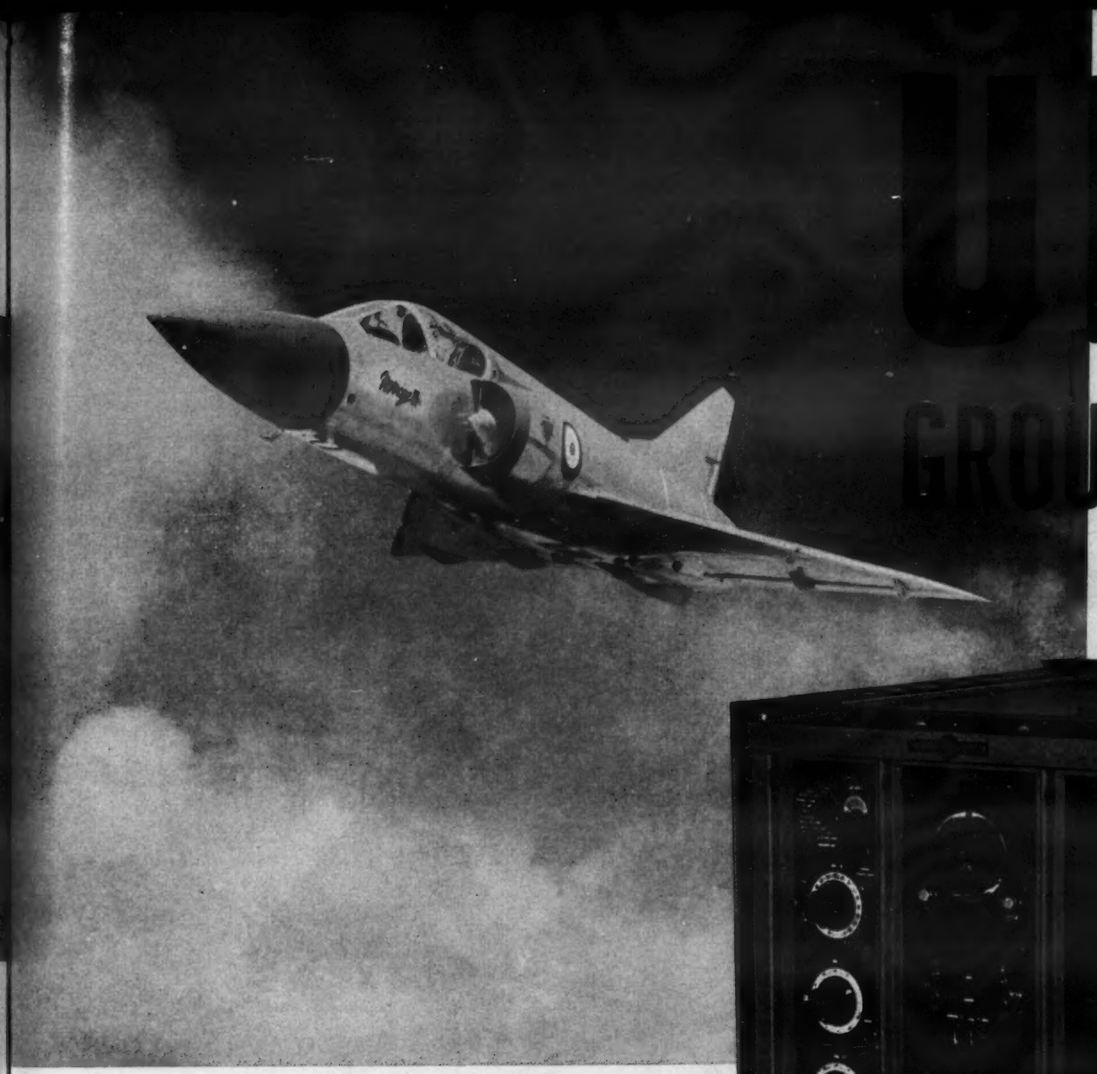

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THOMSON CFTH HOUSTON

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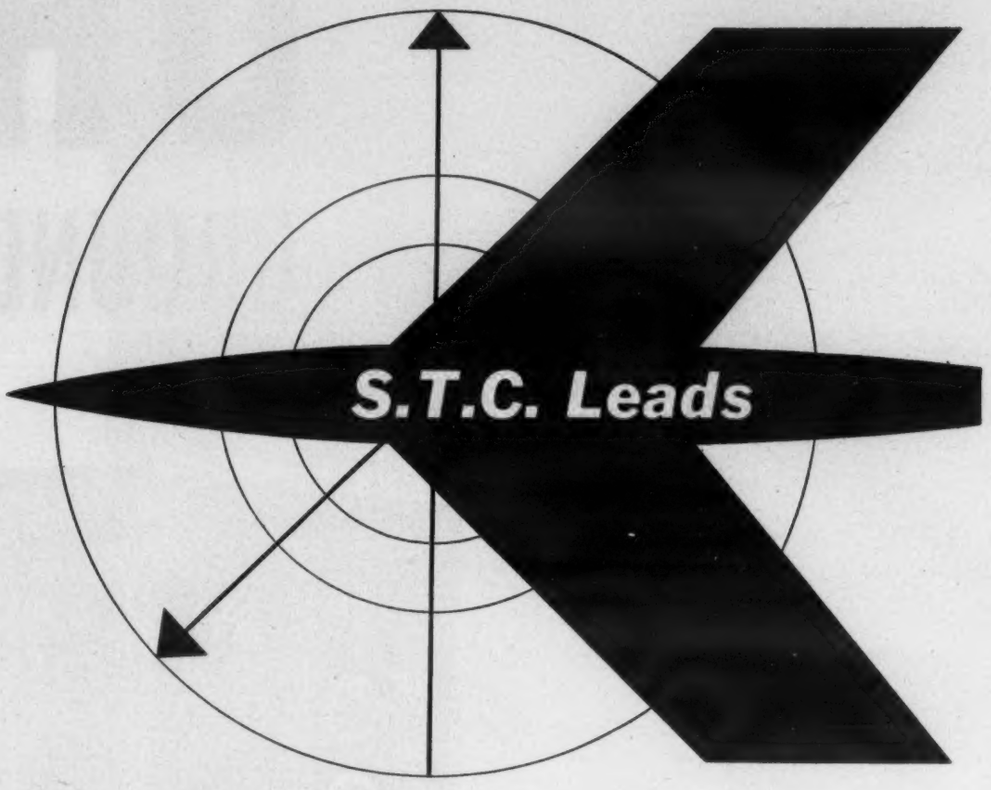

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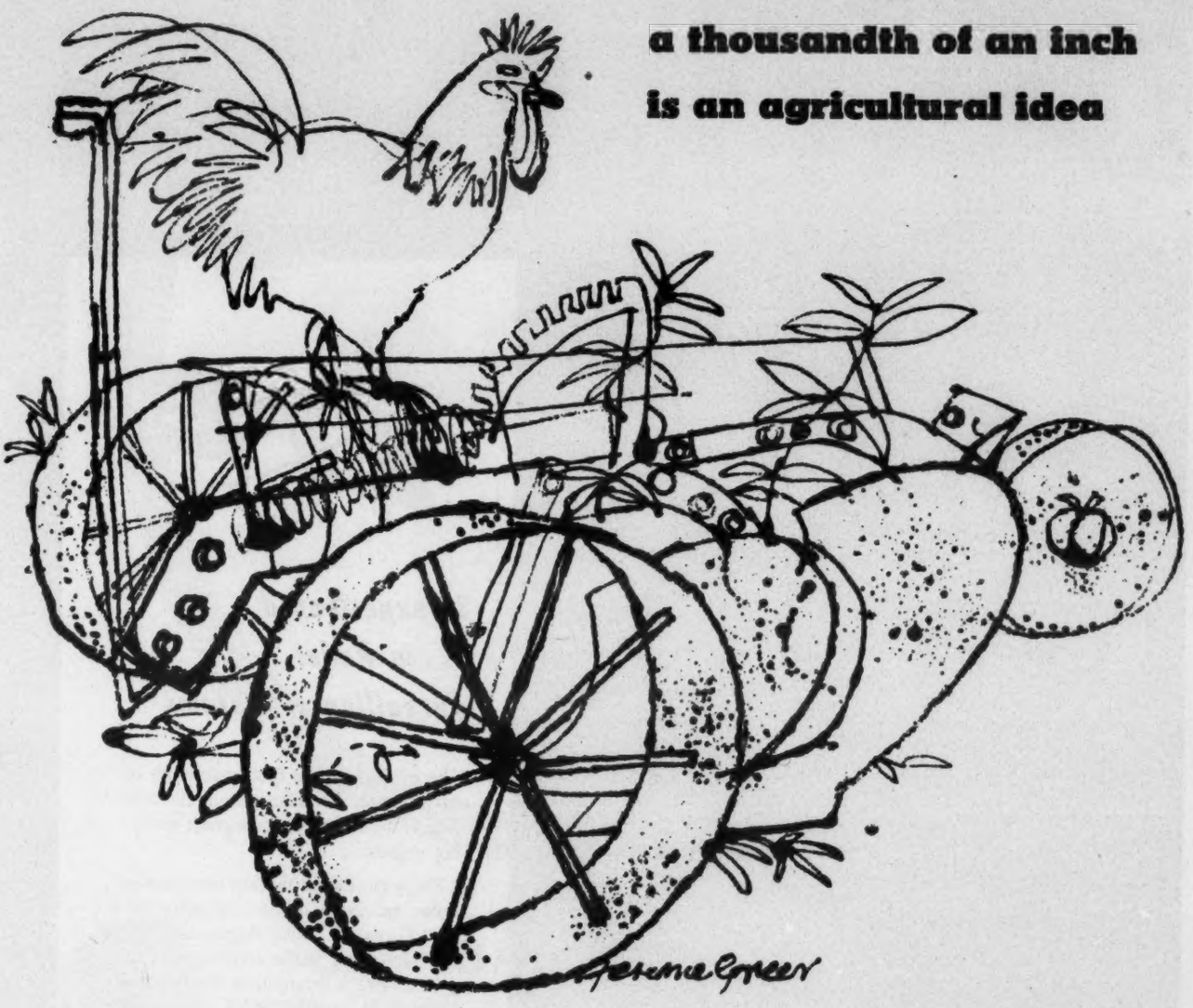

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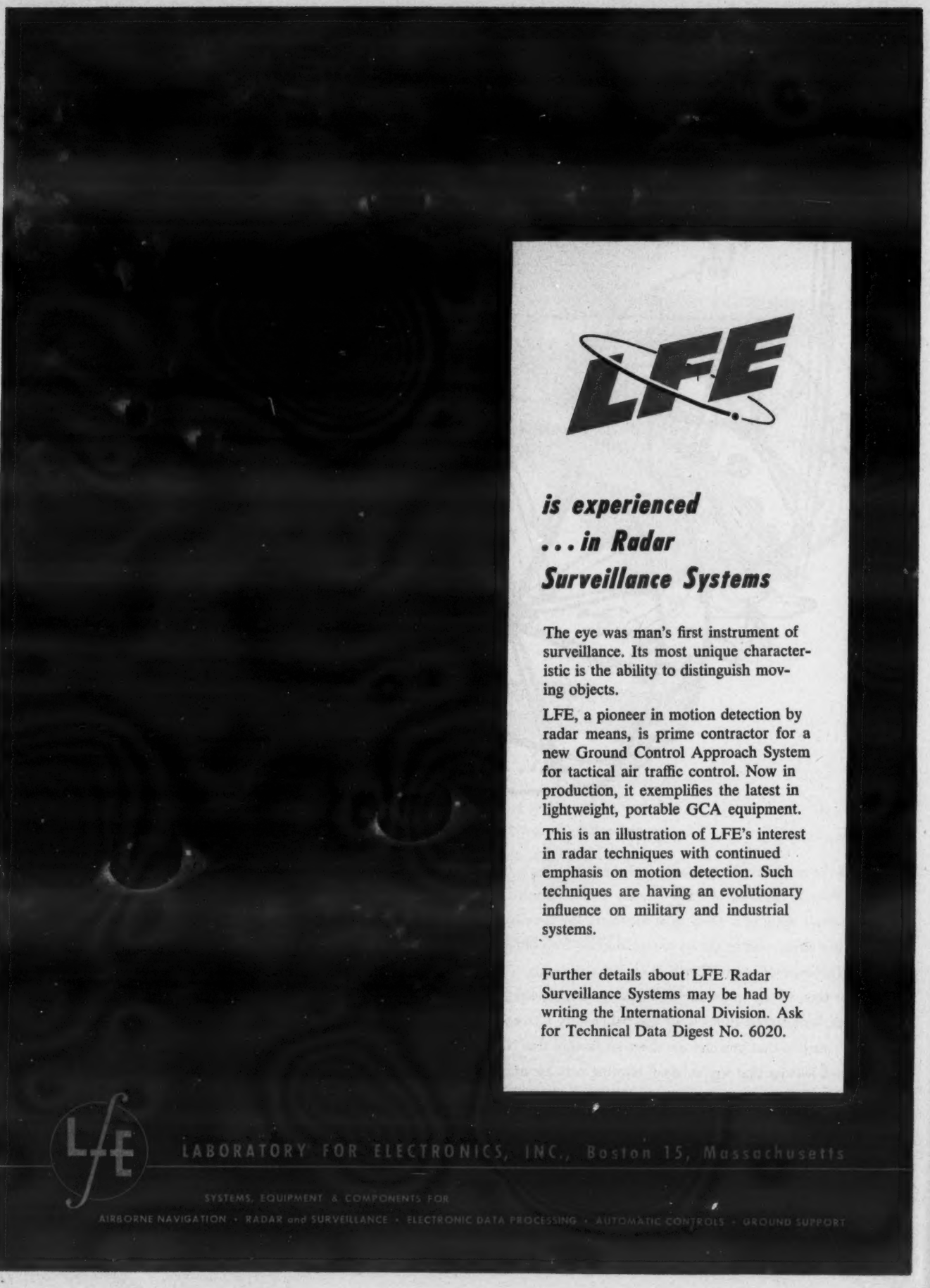

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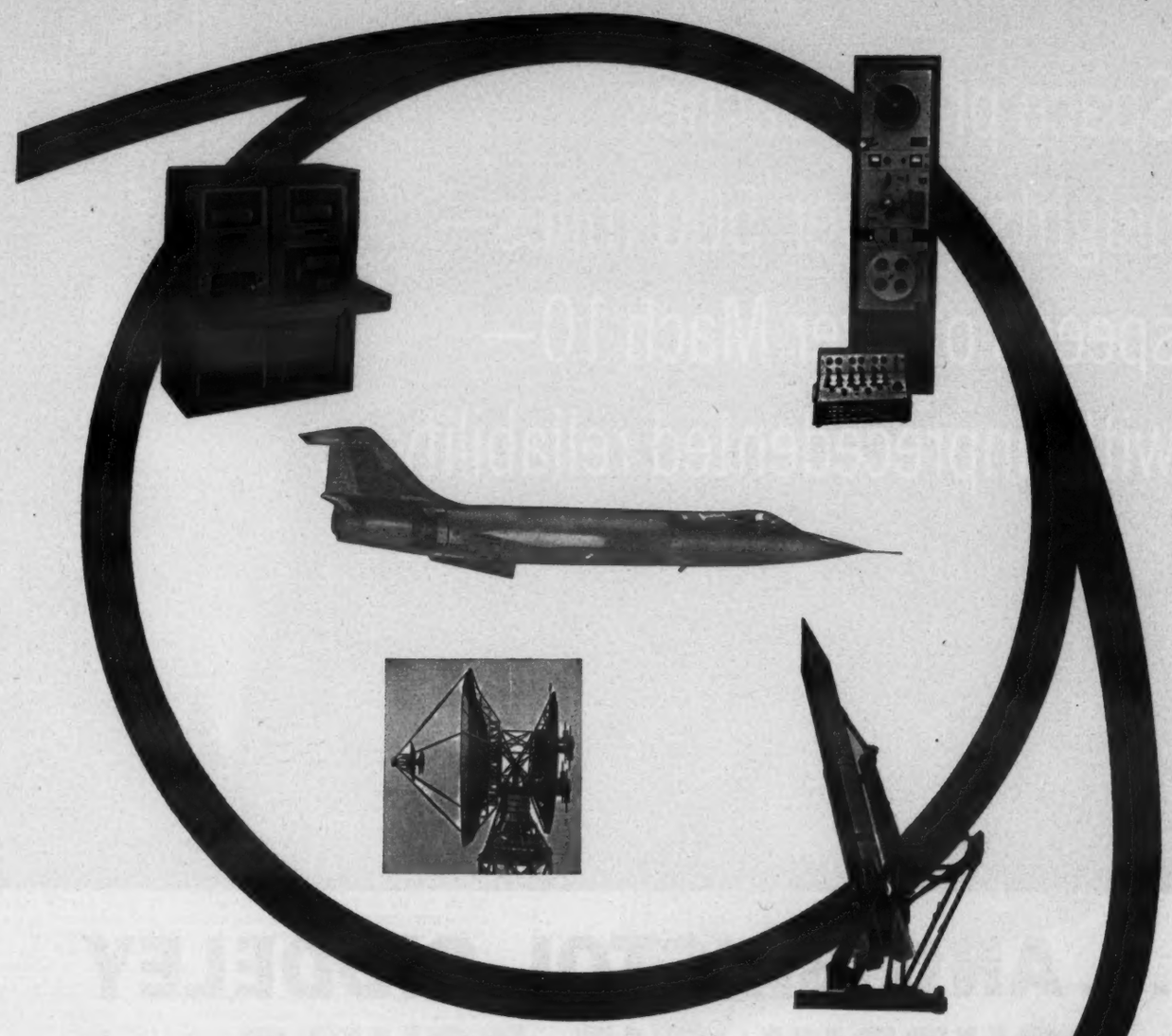

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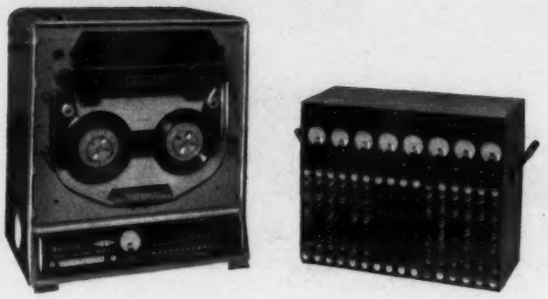
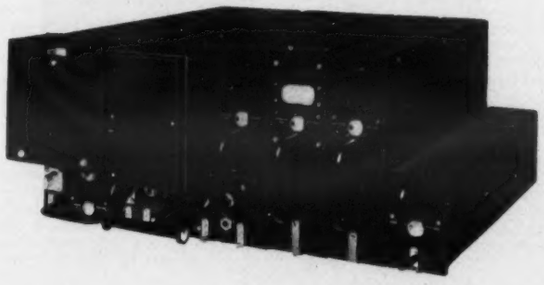
Electronics at Farnborough



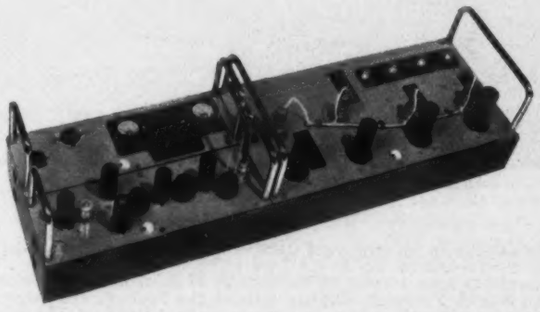
● **Elliott Brothers (London) Ltd.,** a member of the Elliott-Automation Group, announced the production of a new multi-channel tape recorder. The equipment is designed primarily for instrumentation work, particularly in aircraft flight-testing and in missile telemetry applications. At the same time it also has excellent voice reproduction characteristics for studio use. The tape transport system employs dual capstans and take-up assemblies and the use of the dual capstan drive reduces disturbance of the tape in contact with the heads as it is wound onto and off the reels. The recording and play-back heads are duplicated, which makes it possible to reverse the tape direction. Five head stacks are fitted including the erase head. The tape speed is selected by means of a push-button control, and five settings from $1^7/_8$ inches per second to 30 inches per second are provided. It is possible to handle signals up to 70 Kc/s frequency at 30 i.p.s. At $1^7/_8$ i.p.s., the lowest speed for the standard version, the single track duration with 2,400 feet of thin-base tape is 256 minutes. The maximum number of tracks on one-inch tape is sixteen and as the instrument has both direct recording and f.m. facilities it can handle a great variety of different inputs. In the illustration the recorder is shown on the left, with the record and play-back amplifier next to it.



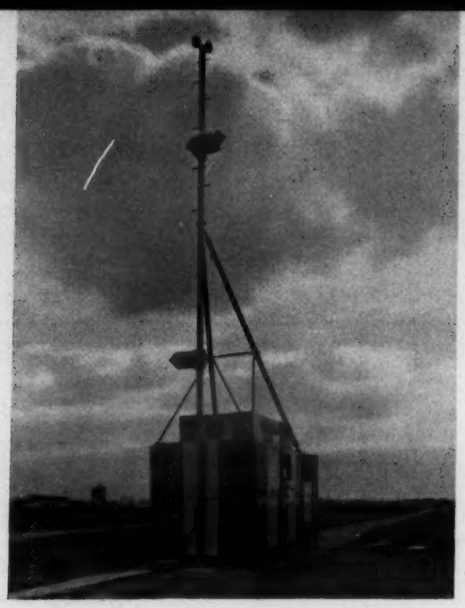
● **Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex,** announced two developments in the field of electronic engineering. The first is a new range of airborne radio equipment and navigation aids, described by the manufacturer as the "Sixty" series. These are fully transistorized with the exception of the VHF transmitter output stage, and some employ a sealed module construction technique. During the design stages of this equipment, a special study was carried out to determine causes of component failure so as to ensure the maximum operational reliability. The use of transistor circuitry has obviated the problem of heat dissipation and in consequence it has been possible to design sealed modules which enable the components to operate in conditions which approach the ideal. In the Navigation unit 6402, the Marker receiver 6403, and the Glide Slope receiver 6404, this has been done by dividing the equipment into sealed modules filled with dry, inert gas. Should a fault appear in a unit, the modules can be tested without being unsealed. The new circuitry design has also resulted in smaller and lighter equipment without the necessity for extremes of component miniaturization. The illustration shows the various units of the "Sixty" series. From left to right these are: the AD 360 automatic direction finder which provides a continuous crystal controlled tuning from 100 Kc/s to 1799.5 Kc/s in 0.5 Kc/s steps and weighs $18^1/_2$ pounds; the AD 160 VHF transmitter giving 360 crystal controlled channels between 118 Mc/s and 135.95 Mc/s, and weighing 14 pounds; the AD 160 receiver which covers 108 to 135.95 Mc/s and weighs 9 pounds; the AD 260 navigation unit; the AD 260 glide slope receiver and the AD 260 marker receiver. The weight of the complete installation is $59^1/_2$ pounds.

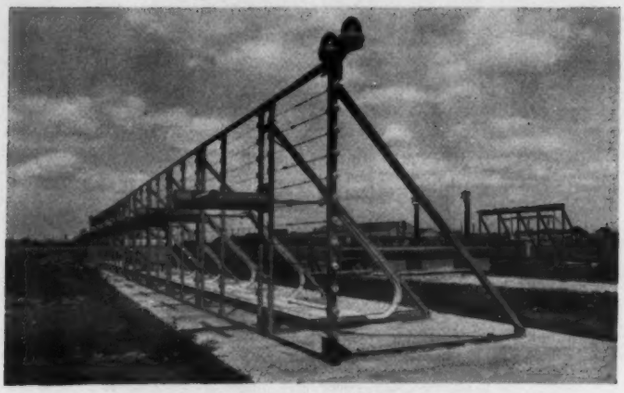
It has been announced that the BOAC fleet of 35 Vickers VC.10 aircraft are to be equipped with the "Sixty" series of communications equipment. Some 1400 main units will be manufactured to fulfil this order.

The second new development is in the field of radar and consists of a parametric amplifier which promises to give a considerable improvement in signal/noise ratio. The device is designed for eventual incorporation in new Marconi 50 cm radar equipment and will probably also be available as a modification kit for existing installations. It is anticipated that incorporation of the amplifier in a 50 cm radar will increase the range by 25 percent—equivalent to more than doubling the power. The picture shows a development model of the frequency amplifier.



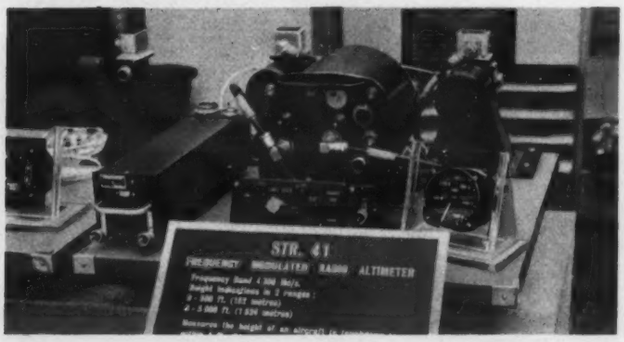
● **Standard Telephones and Cables Ltd., London,** displayed the new automatic direction finding triangulation equipment, type PVT.2, which employs closed-circuit television techniques to distribute the information throughout the air traffic control centre. The equipment receives directional information over telephone lines from a network of widely-spaced receiving stations and converts it into a triangular display of aircraft position. In the picture synthesizer (centre of picture) the bearing displays are combined optically with an illuminated map and scanned by a television camera. The picture is then transmitted over a closed circuit to various positions in the air traffic control centre to provide a continuous source of information to the control personnel.





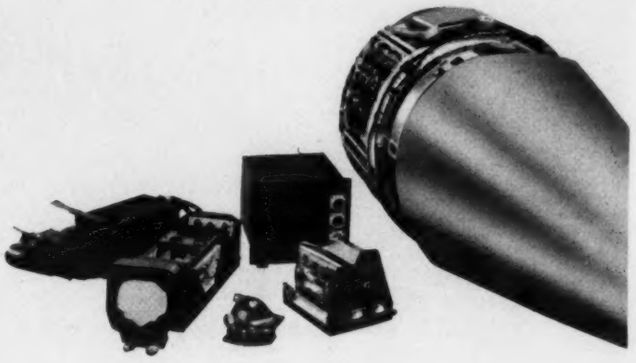
Other exhibits on the company's stand included a localizer transmitter and remote control unit for the STAN 7/8/9 Instrument Landing System. This equipment has been adopted by the Ministry of Aviation for installation at London Airport, Prestwick, Ringway, Gatwick and Renfrew. The transmitter arrays for the glide path and localizer beams are illustrated here. The localizer installation consists of two aerial arrays with the transmitter housed in the sunken building between them. In the foreground is the "course" aerial array (85 feet wide by 12 feet high) and in the background is the "clearance" array (9 feet wide by 13 feet high). The clearance pattern is an indication to the pilot as to which side of the approach runway he is flying, upon reaching the narrow course radiation pattern his receiver indicates the information from this narrower and stronger beam. This dual transmission system gives greater freedom from course bends resulting from site imperfections and from dangers of radiating false course information. This is achieved by the use of an extremely narrow beam for course guidance and the clearance radiation pattern which effectively masks any reflections which may arise from secondary lobes.

Also on display were three radio altimeters which have been designed for automatic landing applications. The STR 30 B1 has been used in the Ministry of Aviation's Autoland system for over 4,000 landings. The STR 40 is a new single range instrument giving height indications from 0—500 feet which has been designed for use with an automatic landing system, while the STR 41 is a two range instrument giving indications from 0—500 feet and 0—5,000 feet. This is a general purpose instrument suitable for both military and civil use and is in quantity production for the Royal Air Force.

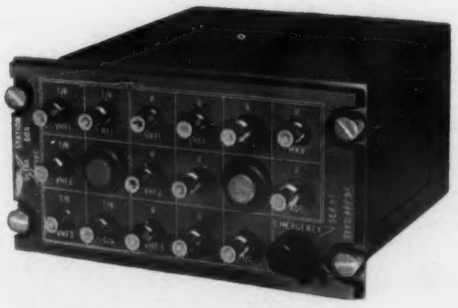


● **Ferranti Ltd., Manchester,** displayed examples of airborne radar and fire control equipment including the AIRPASS I (Airborne Interception Radar and Pilot's Attack Sight). The company is also engaged in the development of a Mark II version of this system as a private venture and this has been specified for the export versions of the *Lightning*, SAAB *Draken* and Dassault *Mirage III*. The units of the *Airpass II* system are illustrated. From left to right these are the attack sight, the search display, hand control, two auxiliary circuit units and the radar unit with nose radome.

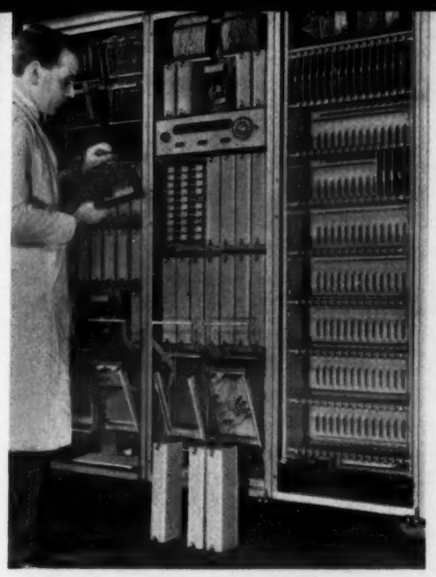
In comparison to *Airpass I* which is purely an interception system designed for the *Lightning*, the developed model provides weapon aiming both by day and night together with automatic navigation facilities. The radar can be used for search and tracking of air targets and also for terrain mapping and target ranging of ground targets. For operations requiring low altitude penetration to obtain protection from enemy defences, it can also be used in a profile flying mode. Steering signals are presented on the sighting display which enable the pilot to follow a selected course at low altitude and to clear any hills or ground obstacles in safety.

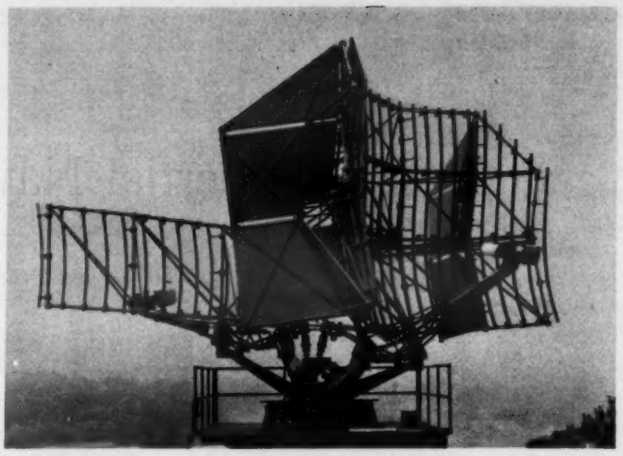


In the field of civil aviation, Ferranti Ltd. is at present engaged in installing an *Apollo* computer at the Scottish Air Traffic Control Centre, Prestwick. This machine is the first of its type to be used for air traffic control experiments in Great Britain and its installation points to the coming era of automation in this sphere. It will go into operation in early 1961 and will be employed in the control of the North Atlantic oceanic routes.

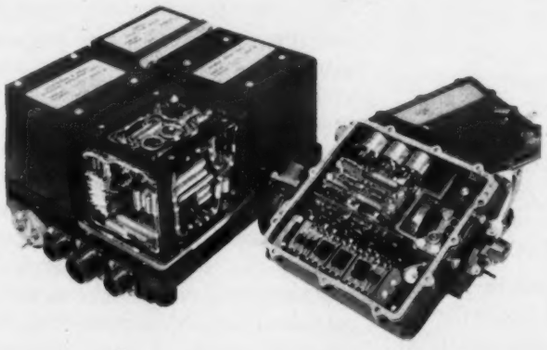


● **Ultra Electronics Ltd., London,** demonstrated the UA 60 Communication Control system. The basic station box incorporates fifteen push buttons for the selection of transmitters, receivers, inter-communication and cabin address facilities. The push buttons are divided into two groups by a double white line and the five buttons to the left of this line control the transmitters. Selection of any transmitter automatically selects the associated receiver, but the receiver alone can be selected if required, by a push button in a corresponding position to the right of the double white line. A total of up to nine receivers can be operated simultaneously, each receiver push button incorporating an integral volume control. A separate button controls inter-communication facilities and there is an over-ride circuit which ensures that all crew members receive priority intercom messages irrespective of whether or not they have selected the intercom service. Arrangement of the push buttons will vary from installation to installation, but a typical system might control two VHF transmitter-receivers, two HF transmitter-receivers, ADF, ILS, and VOR receivers, and cabin address and intercom.



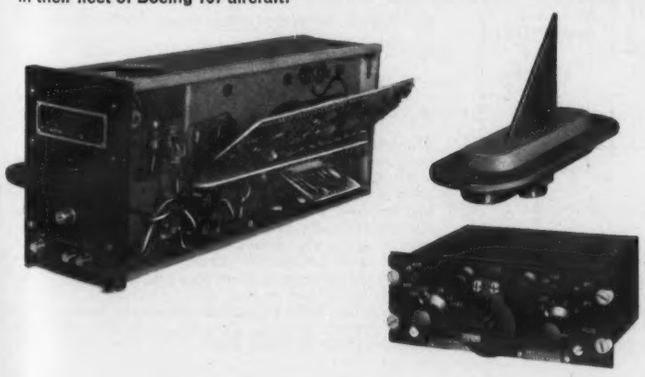


• **De Havilland Propellers Ltd., Hatfield,** announced two new developments in the electronics field. The first, designated ACORN, for Automatic Checkout and Recording equipment, is intended for the comprehensive testing of complex systems in aircraft, missiles and ground equipment. Each data channel is scanned and checked at a rate of one per second and the results are permanently recorded by an electric typewriter. The second new development is a fully automatic electronic fuel control unit for use in helicopters. Using this equipment, the pilot selects the desired rotor speed and the computer automatically maintains this speed throughout the flight. The illustration shows the computer together with the mechanical throttle linkage.



• **Decca Radar Ltd., London,** displayed the DASR-1 air surveillance radar and aerial installation. This is a 10-cm, double beam radar with two 800 kW transmitters feeding an aerial system consisting of separate high and low cover aerials mounted back-to-back. A separate receiver channel is associated with each aerial and the received signals are displayed on traces spaced 180 degrees apart on the PPI displays. This provides a continuous and simultaneous presentation of echoes from both beams. Flight trials have shown the radar to be capable of tracking an aircraft from the full display range of 120 nautical miles at heights in excess of 40,000 feet. Low altitude cover is such that aircraft have been tracked to below 500 feet at a range of 18 nautical miles. Working in conjunction with *Ampex Electronics Ltd., Reading,* Decca Ltd. has developed a high fidelity radar tape recorder which is intended for civil and military use as an aid to training, analysis and research. The equipment is capable of recording and playing back the data from a single beam surveillance radar; later versions will be available for use with multi-beam aerials. The recorder uses two inch tape carried in 7,200 feet reels and the tape speed is 15 inches per second. Four channels are provided which cover video, speech and aerial bearing information while the fourth carries a control signal which ensures alignment during playback. The development of effective radar recording techniques indicates that there will be a future requirement for the recording of air surveillance data to aid in the analysis of situations where accidents have occurred. As the tape can be erased and reused it would appear that magnetic recording offers the cheapest solution to this requirement.

• **Cossor Radar & Electronics Ltd., Harlow,** provided a working display of a secondary surveillance radar system. The ground element of the system is the Cossor SSR4G interrogator responsor and the combined interrogation and control aerial. The airborne installation illustrated here consists of the SSR1251 transponder, a control unit and a fin type omnidirectional aerial. An important feature of this equipment is the sidelobe suppression system employed to give accuracy of interrogation and response. Sidelobe suppression has been recommended by ICAO and has been stated as a requirement by both the Federal Aviation Agency and the British Ministry of Aviation. The current ICAO specification is for a "2-pulse" system but an alternative "3-pulse" system has been the subject of recent discussion and may also receive international approval. The Cossor ground equipment can be supplied to work with either system, and the airborne equipment, which is currently supplied to operate in the "2-pulse" mode, can be modified for use also with the "3-pulse" mode. The transponder has recently been adopted by BOAC for installation in their fleet of Boeing 707 aircraft.



Inertial Navigation Systems*

by Eduard M. Fischel, Kearfott Division, General Precision Inc., Little Falls, New Jersey

The problem of inertial guidance has occupied forward-looking engineers for some 40 years, but the first successful inertially guided flight took place only nine years ago. Development has been long and thorny, and even today has not yet reached its final stage, in spite of the fact that the principles have not greatly changed. In our opinion, no radical changes in the basic principles are to be expected, though there will be improvements in components and hence in overall system performance.

I. Inertial navigation systems for ships and aircraft

Inertial navigation and guidance systems are based on measuring the acceleration in three orthogonal directions, followed by single and double integration with reference to time. This gives the momentary velocity and position of the vehicle in a chosen reference system. The reference system is based on the inertial characteristic of the gyroscopes, which tends to maintain them in a fixed orientation in inertial space. Its accuracy depends primarily on the ability of the gyroscopes to maintain this orientation despite the disturbing factors which may be present.

The kind of reference system chosen depends on its application and on the preference of the designer. Many different solutions are possible, but I shall restrict myself in this paper to one application for aircraft and ships, and one for rockets.

The method most frequently used for vehicles has the rotating earth as reference; the device is always parallel to the earth's surface, and its azimuth points to the North Pole. The advantage of this method is that the position of the vehicle is determined directly in terms of latitude and longitude.

A simplified diagram of such an arrangement is reproduced in *fig. 1*, which shows a gimbaled platform equipped with an azimuth gyro and one or two vertical gyros. In addition, the platform carries three accelerometers which measure the acceleration components a_x, a_y, and a_z corresponding to latitude, longitude and altitude. Direction x is chosen as north-south direction.

The accelerations thus measured are then integrated with respect to time in the associated integrators, which yield the velocity components V_x, V_y and V_z in the above-mentioned coordinates. These values would be correct if they were referred to inertial space. However, as they are related to the spinning earth, allowance must be made for the Coriolis effect by introducing apparent forces into the accelerometer, for correction purposes. In addition, compensation must be made for centrifugal accelerations due to the earth's rotation and the vehicle's motion.

Furthermore, steps must be taken to keep the gyro platform tangent to the earth's surface. Even when the vehicle is stationary, the gyro platform must follow exactly the earth's rotation; this is achieved by precessing the gyro about two or three gimbal axes (compensation for earth's true rotation). With the vehicle in motion, its angular velocity must also be considered; this is done by dividing the computed velocities V_x and V_y by the earth's radius (compensation for earth's "apparent" rotation).

In this way, two oscillatory loops are created in the navigational system, comprising the accelerometers, the first integrator stages, the computers which carry out the division by the earth's radius and the corresponding gyros. They are shown in heavy lines in the figure. For correct performance, i.e., to separate the vehicle's accelerations from gravitational accelerations, each loop must be tuned to a period of 84 minutes.

* Extracts from a paper read to the 4th European Aviation Conference (September 18th to 22nd, 1960) at Cologne. The complete text will be published in the Wissenschaftliche Gesellschaft für Luftfahrt's 1960 Yearbook.

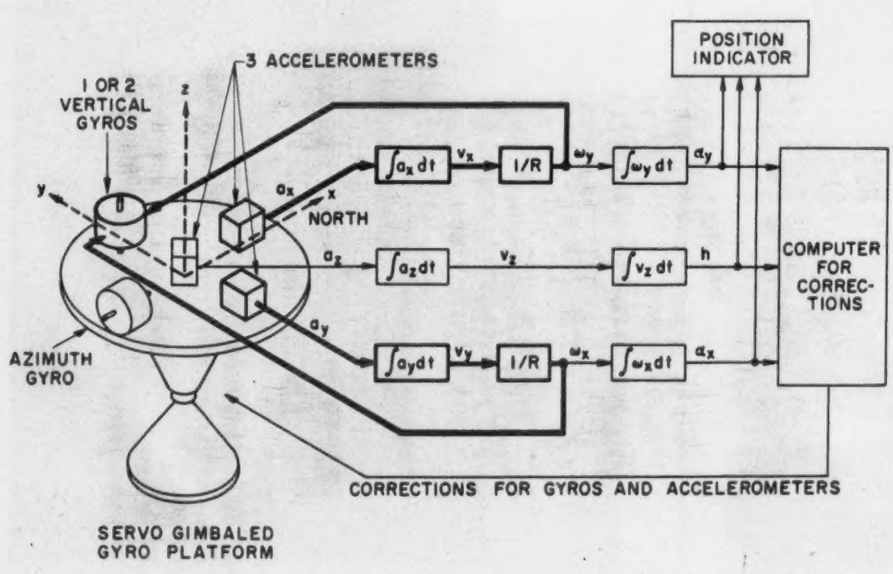


Fig. 1:
Simplified diagram of an inertial navigation system for aircraft and ships: left, the servo gimbaled gyro platform which supports the azimuth gyro, one or two vertical gyros and three accelerometers. The accelerometer outputs are integrated with respect to time, and two of them are divided by the earth's radius (R), giving the angular velocity about the earth's centre. A further integration then gives the changes in latitude and longitude and the variation in altitude with respect to the starting point; this integration can be read in the position indicator. A computer (far right) supplies corrections to the gyros and accelerometers, such as Coriolis effect; the 84-minute loops are shown in heavy lines.

By dividing V_x and V_y by R (earth's radius), we obtain the angular velocities ω_y and ω_x of the vehicle in the north-south and east-west directions. A subsequent integration yields the geographical latitude α_y and longitude α_x, and hence the position of the vehicle. For aircraft which change altitude rapidly and climb to high altitudes, the vertical acceleration must also be measured and integrated, to obtain the vertical speed and altitude. With increasing altitude, the 84-minute tuning period increases automatically. Coriolis effect, centrifugal accelerations and the components of the earth's rotation are allowed for in a correcting computer, which carries the coordinates of the point of departure and is continuously fed with the basic data for the first and second integrations.

*

The 84-minute loops serve to compensate for imperfections in the inertial system components. Errors can be introduced, for example, if the gyro's centre of gravity shifts, causing drift, the accelerometer is not perfectly balanced or the null has shifted in the first integrator.

The upper four diagrams in *fig. 2* show the effects of a constant gyro drift in the Schuler loop. The acceleration error varies in the form of a sine curve, as does also the platform tilt. The velocity error is a cosine curve. The position error increases linearly with time, if the sine wave modulation, which becomes insignificant after a few oscillations, is disregarded.

In addition to its separation of gravitational from vehicle accelerations, the advantage of the 84-minute loop lies in the fact that it limits acceleration, platform tilt and velocity errors resulting from gyro drift, and reduces the increase in position error.

The lower three diagrams in *fig. 2* show the loop errors due to errors in the accelerometer or in the first integrator. Assuming that the acceleration error has a constant value, it creates a velocity error in the shape of a sine curve, and this error in turn creates a position error in the shape of a cosine curve. Steady build-up of the position error resulting from the above-mentioned sources can be prevented by the 84-minute loop.

If the inertial system is associated with additional aids, such as Doppler radar or an automatic star tracker, recurring velocity and position errors can be eliminated.

*

So much for the horizontal attitude of the platform. As regards its stabilization in azimuth, it has already been said that the system constantly points towards the north. Since the azimuth gyro by definition maintains its direction in space, it must be made to precess in order to keep it pointing north. The amount of precession required is determined by the computer.

In evaluating the azimuth error, we assume that the gyro drift errors are greater than the inaccuracies occurring in the precessing operation and so ignore the latter. *Fig. 3* shows how the errors develop with time for an aircraft flying in a straight line at a speed of 240 m/sec. A gyro drift of 0.03 degrees per hour causes an azimuth error of 0.03 degrees after one hour, and the aircraft has developed a lateral velocity of 0.125 m/sec which shifts it sideways. The accumulated deviation after the first hour is 225 m. This in itself would be acceptable, but the error increases as the square of time, so that a gyro with smaller drift will be essential for longer flights. However, here too Doppler radar and star tracking provide means of making corrections.

The error curves shown here are based on the assumption that the cause of the error remains constant, which is seldom the case in practice. Gyro drift, for example, is generally random, so that the present assessment of errors probably leads to somewhat too unfavourable values. Only thorough knowledge of the gyro's correlation functions will enable us to make a more accurate forecast of its probable drift and to undertake programmed corrections.

Finally, it should be added that inertial systems for ships work on the same principles as those for aircraft, differing from the latter in parameters only. An aircraft system must above all be light in weight and can accept a moderate gyro drift, whereas for ships (submarines) the prime requirement is minimum gyro drift and highest precision, since the system is required to operate for much longer periods.

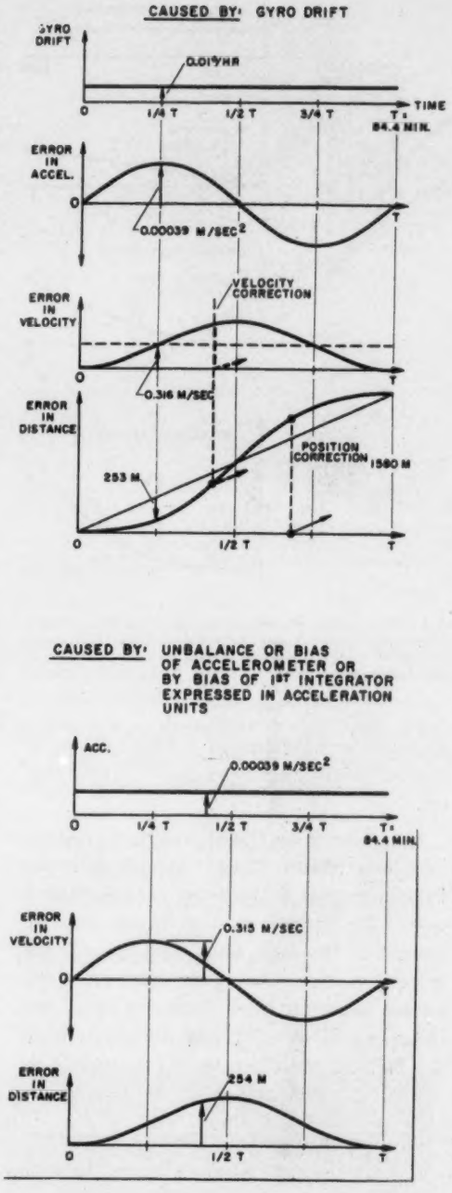


Fig. 2:

Errors in 84-minute loops for north-south and east-west movement components: the four upper diagrams show the effects of gyro drift of 0.01 degrees per hour, in the form of errors in acceleration which follow a sine curve, and the corresponding integration errors for velocity and distance components. Corrections can be made at any time by doppler measurement of the velocity component and astro position fixing (broken lines).

The three lower diagrams, on the other hand, show the effects of a slight unbalance or bias of an accelerometer or bias of the first integrator. These are assumed to be of equal magnitude in all three cases, corresponding to an error of 0.00039 m/sec². The maximum position error in all three cases is 254 metres, and this is reached after 42 minutes.

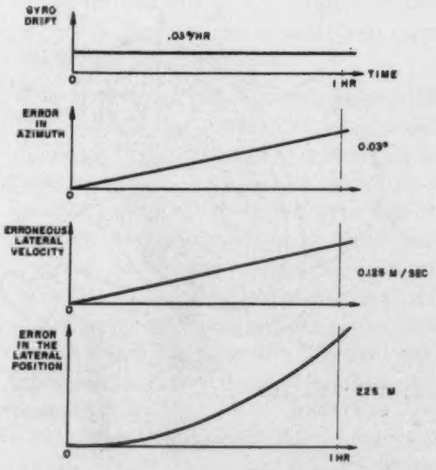


Fig. 3:

Errors due to azimuth gyro drift of 0.03 degrees per hour: the lateral displacement of the ship or aircraft is 225 metres after one hour.

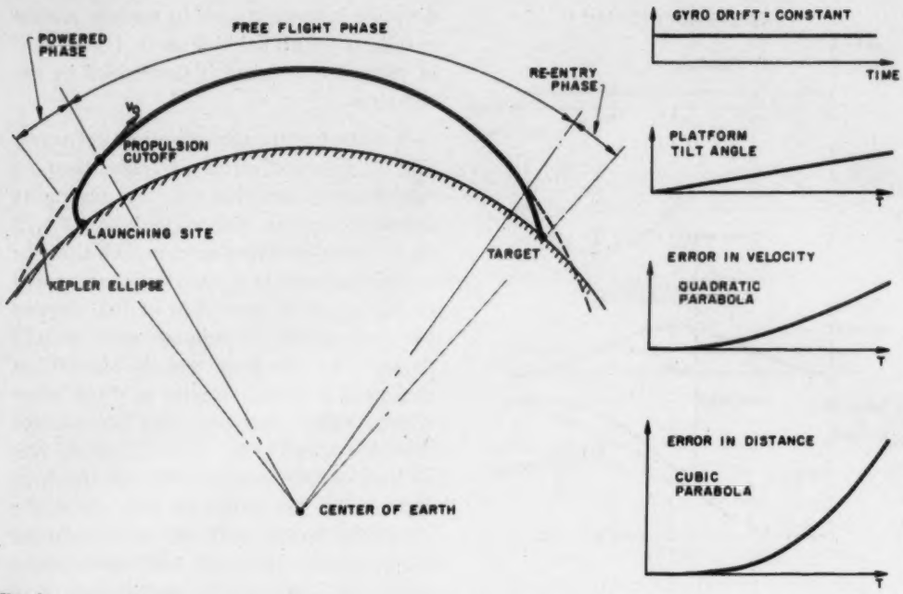


Fig. 4:

Principles of inertial rocket guidance: left, the trajectory of a rocket, in which three phases are distinguished: the powered phase, the free flight phase and the re-entry phase. The rocket can be guided only during the powered phase. The curves to the right show the errors due to gyro drift: the tilt angle of the platform steadily increases, causing the velocity error to follow a quadratic parabola, the distance error to follow a cubic parabola.

II. Inertial systems for rocket and satellite guidance

Guidance systems for ballistic missiles take advantage of the fact that during the unpowered phase these bodies follow a predictable trajectory determined by the conditions at power cut-off and by the properties of the earth's gravitational field. The initial conditions for the ballistic trajectory are the point of power cut-off and the body's velocity in magnitude and direction at that point. The shape of the trajectory is a segment of a Kepler ellipse at a great height above the earth in very thin air.

Fig. 4 shows an ICBM trajectory, divided into three phases. Phase 1 extends from the launching point to the power cut-off, phase 2 covers the ballistic portion (more than 80 percent of the flight time), and phase 3 the re-entry portion. During the latter phase the missile begins to slow down owing to the increasing air density, and deviations from the ballistic trajectory occur, depending on drag and missile weight. To minimize these effects, the dense and aerodynamic nose cone is often separated from the missile body.

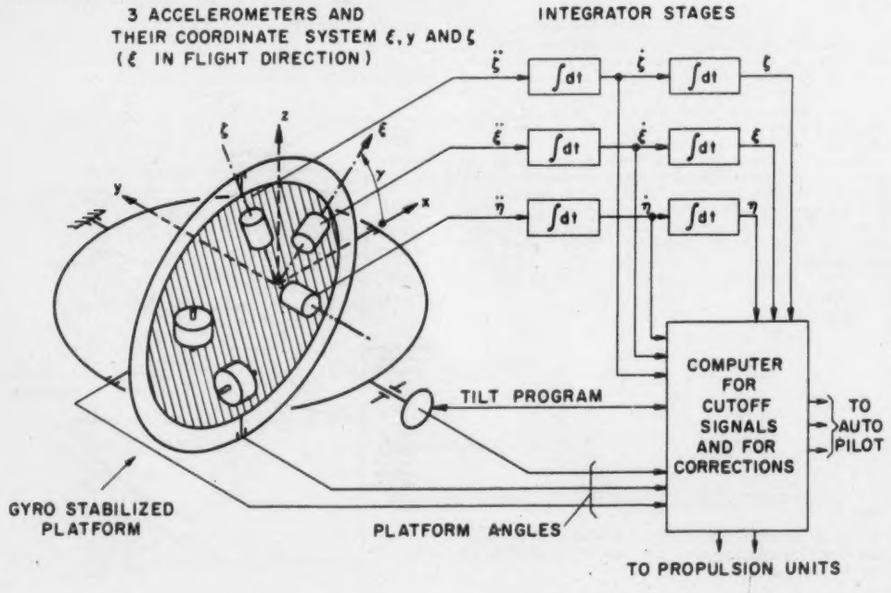
It is obvious that guidance is restricted to the propulsion phase. The inertial guidance system determines the position and velocity of the missile in magnitude and direction and cuts off the power when the computer shows the required conditions are met. In this application, too, the missile's velocity and position are obtained by single and double integration of the accelerations measured along the three orthogonal coordinates, while the reference system is stabilized by an inertial platform. However, the reference system is stabilized in space, while the target on the spinning earth is computed back into earth coordinates. In most cases the gyros are kept free from precessional motion and consequently remain "free in space." Because the propulsion phase is so short, Schuler tuning of the vertical loops would not be helpful, but would merely unnecessarily complicate the platform system. Admittedly, increasing velocity and position errors occur as a result of gyro drift, as shown in the curves on the right-hand side of *fig. 4,* but they are numerically small and contribute little to the missile's inaccuracy at the target. The total target error depends primarily on the accelerometer and integrator errors, the drift of the azimuth gyro and the accuracy with which the platform is erected (in azimuth and vertical) before launching.

Even small velocity and azimuth errors considerably affect accuracy at the target. An ICBM with a range of 8,000 km (5,000 miles) has a burnout velocity of 6,000 m/sec, which must be accurate to within ⅓ m/sec if the target error is to be restricted to 1 nautical mile (1,850 m). This means that the error in velocity measurement must be less than one part in 20,000. Similarly, an error of 0.01 degrees in azimuth will also result in an error of one nautical mile at the target.

Fig. 5 is a simplified diagram of a rocket guidance system. The readings from the three orthonogonally mounted accelerometers are fed into the integrators and thence into the computer which determines cut-off point and necessary corrections. The computer also supplies the signals for the missile's guidance. The tilt of the misslie trajectory is also programmed during the power phase. The accelerometers in the plane of flight are tilted backwards by an angle γ in order to orientate the x-accelerometer in the direction of the main acceleration, and the z-accelerometer perpendicular to it. In this way the x-unit measures essentially the large accelerations in the flight direction, and the z-unit the per pendicular component which requires a smaller range.

Fig. 5:

Simplified diagram of a rocket inertial guidance system: the platform, which is gyro-stabilized in space, supports three accelerometers with orthogonal axes of measurement, one of which is parallel to the climb trajectory. The integrator outputs feed a computer, which in turn controls the rocket's autopilot, ensures that the tilt programme is carried out and transmits the cut-off signal.


3 ACCELEROMETERS AND THEIR COORDINATE SYSTEM ξ, y AND ζ (ξ IN FLIGHT DIRECTION)
INTEGRATOR STAGES
∫dt
COMPUTER FOR CUTOFF SIGNALS AND FOR CORRECTIONS
TILT PROGRAM
TO AUTO PILOT
GYRO STABILIZED PLATFORM
PLATFORM ANGLES
TO PROPULSION UNITS

III. Main components of navigation system

A. The gyro

The rate-integrating gyro designed by MIT (*fig. 6*) is today considered as the main representative of its kind. This is an electrically driven gyro carried in a sealed float structure supported in a fluid. Low friction bearings are mounted on its precession axis. Since the fluid supplies a buoyant force approximately equal to the weight of the float, the bearing load is almost negligible. The fluid film between float and housing offers a resistance proportional to their relative velocity. An electric pick-off senses rotation. The gyro responds to rotation about its input axis by precessing, and the precessional velocity is integrated by the damping action, so that the precession angle measures rotation about the input axis.

The servo motor loop of the platform supporting the gyro receives a guidance signal and forces the platform and the gyro output axis to return to their initial positions. The gyro is capable of stabilizing only one axis in space. In addition to this type, there are gyros with two degrees of freedom, which also are floated to reduce bearing friction.

The high degree of precision attained as the result of 10 to 15 years of development and manufacture is due to a judicious choice of materials, the precision of the components, clean and careful assembly and accurate balancing of the float. Such gyros are expected to drift less than 0.01 degrees per hour. As they do not drift consistently in one direction, this "standard deviation" is considered to be an average value over a limited time (several hours). As an exercise in arithmetic, it can be calculated that a gyro with a drift of 0.01 degrees per hour would take four years to rotate 360 degrees.

The following are three examples of the stringent technical requirements connected with the manufacture of a gyro:

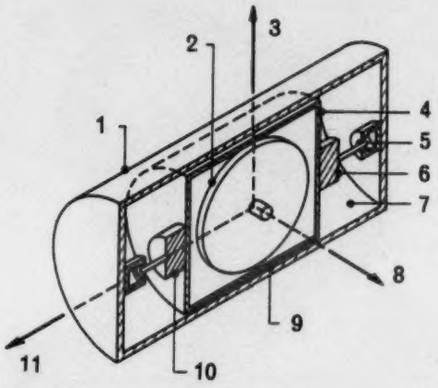


Fig. 6:
Diagram of the MIT-designed rate integrating gyro. 1 — housing; 2 — flywheel; 3 — input axis; 4 — float; 5 — jewel bearing; 6 — signal generator; 7 — space filled with fluid; 8 — spin axis; 9 — gap between float and housing; 10 — torquer; 11 — output axis. — The best material for the gyro wheel, which has a diameter of only 48 mm and a thickness of 10 mm and rotates at 24,000 r.p.m., is steel, while beryllium is preferable for the float.

- A steel rotor having a diameter of 4.8 cm and a thickness of 1 cm, weighs 150 grams and spins at 24,000 r.p.m. If the rotor's centre of gravity shifts only 3.2×10^{-6} mm from its exact precession axis, drift will reach a value of 0.01 degrees per hour. It must be remembered that this shift can take place not only in the rotor itself, but also in its bearings or in the float housing.

- A decisive factor is the ratio of the rotor's angular momentum to its weight. Only the mass of the rotor contributes to this momentum, while the weight of the float assembly must be kept as low as possible. If beryllium is used for the float instead of steel, weight can be reduced to one sixth without any loss of rigidity. However, this material costs more and is more difficult to work.

Fig. 7:
Gyro housings being evacuated and filled at the Kearfott Division of General Precision Incorporated.

- Because of the close tolerances in the jewel bearings, in the gap between float and housing, in the pick-off and torque producers, it is imperative that even the smallest dust particles be kept out of the assembly. Special assembly areas and special work clothes are provided, and the air is continuously filtered to exclude all dust particles above 0.3 microns (0.0003 mm). Although particles of this size are not directly detrimental to the gyro performance, they may become dangerous by agglomerating.

Fig. 7 shows the equipment used to evacuate the gyro and fill it with fluid. Here it is of the

Fig. 8: Final assembly of a gyro . . . with gloves.

utmost importance that even the smallest traces of gas be removed. *Fig. 8* shows an assembly booth, with a gyro in the process of final assembly. The worker is separated from the work piece by a glass plate, and only his gloved hands can reach the gyro through narrow openings. *Fig. 9* shows the miniature gyro manufactured by the Kearfott Division of General Precision Inc.

B. The accelerometer

The most widely used accelerometer today is an electro-magnetically compensated pendulum, consisting of a mass fastened to a lever supported by a flexible joint. The mass supports two coils; on the left the air coil of an inductive pick-off, and on the right the moving coil of an electromagnetic torquer. The pick-off generates a signal which, after being amplified and rectified, is fed into the torquer coil, where it produces a force in the field of a permanent magnet. This force counteracts the deflection of the pendulum, and since the current is proportional to the acceleration, it supplies an analogue measure of that acceleration.

The requirements which an accelerometer has to meet are extremely severe: it is expected to measure an acceleration of up to 20 g, while responding equally well to one of 1/10,000 g. Its size should not exceed a few centimetres, and it should weigh little more than 100 grams. It must be capable of supplying correct measurements even when its support is vibrating and must withstand shocks of 60 g.

If this accelerometer, whose direct current output is the analogue of the acceleration at a given moment, is associated with a digital integrator, the direct current must be converted into pulses. The average number of pulses per second corresponds to the amount of current and hence to the acceleration, while the sum of the pulses represents the time integral of the acceleration or, in other words, the velocity.

Fig. 9:
The Kearfott Miniature Floated Rate Integrating Gyro. This miniaturized, fluid-filled gyro for integrating rotation speed revolves at 24,000 r.p.m. and is driven by a subminiaturized three-phase motor (30 volts — 400 c/s). When used as an azimuth gyro, the instrument has an average drift of 0.015° per hour, when used as a vertical gyro a drift of 0.003° per hour. Its operating temperature is 66° C, with a maximum warm-up time of 5 minutes at room temperature and 10 minutes at — 62° C. Total weight 0.84 lb; length 3 inches.

Fig. 10:
The Kearfott miniature accelerometer is suitable for the navigation, guidance and stabilization systems of ships, aircraft and rockets. It can measure accelerations of up to 20 g; its scale factor is 5 mA/g and its null error is 20 seconds of arc. Operating temperature is 155° F ± 5° F. Max. weight 4 oz; length 2 inches.

Besides this compensation pendulum, there are two other devices which have proved their worth in the measurement of accelerations. The first consists in principle of a mass supported in the centre of a wire under tension, and made to vibrate at its natural frequency. As the accceleration varies, so does the frequency, generating an output proportional to the acceleration. The second device is a so-called gyro pendulum, in which a pendulum provokes a precession motion in the gyro, under the influence of the acceleration. The precession velocity here provides a measure of the momentary acceleration, while the precession angle represents the direct integration in relation to time and hence the velocity.

Fig. 10 illustrates the Kearfott miniature accelerometer for space vehicles and long-range rockets.

C. The computers

Yet another group of high precision devices is formed by the computers. These perform mathematical operations such as integration of acceleration and velocity, computation of earth's rate components, centrifugal forces, system functions in conjunction with associated equipment, etc. Some computers are still based on the analogue principle, though digital computers are coming increasingly to the fore, since they offer a higher degree of precision combined with lighter weight and smaller size. Transistors have also largely replaced electron tubes in the amplifier circuits. To complete the picture it should be added that the computer reference voltage must often be kept constant to within 0.01 percent.

Fig. 11: Assembly in dust-free, slightly pressurized rooms.

To sum up, it can be said that the work of the past 15 to 20 years has turned the old dream of an independent navigation system into reality. Dr. Draper's first fully inertially guided transcontinental flight in 1953 proved the soundness of the principle. Since then a number of American companies have developed and tested inertial navigation systems for aircraft and missiles, and quantity production has begun. At the same time size, weight and power requirements have been greatly reduced. Accuracy and reliability have also been substantially increased, and there is every likelihood that they will be improved still further. ←

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Lunar Landing Problems

by Kurt R. Stehling, National Aeronautics and Space Administration, Washington, D.C. *

The landing of a spacecraft or a payload on the moon may be an important part of our coming space technology. There are three methods of placing a payload on the moon, as follows:

1. *Hard Landing*: this presumes no slow down and a direct impact at about 8,000 feet per second. This has been achieved by a Russian lunar firing. There is some possibility of designing spacecraft or payloads which could survive such an impact, but a more practical situation is—

2. *The Rough Impact*, where the spacecraft is partly slowed down by some backward firing or "retro" propulsion system. This scheme is used in the coming NASA *Ranger* program. If the spacecraft has still to be protected from the severe jolt encountered by the rough landing, then—

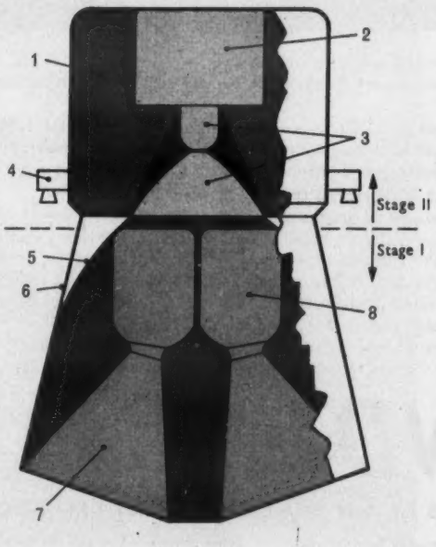
3. *The Soft Landing* is necessary. This presumes that the 8,000 feet per second lunar approach velocity is cancelled, and the spacecraft settles on the moon with no more impact than is suffered, for example, by an aircraft landing on the earth. It should be obvious that this form of landing is a *must* for any manned lunar exploration.

While propulsion questions are discussed here in a very brief way, it must be remembered that the guidance and control problems of a lunar flight are very considerable. However, various spacecraft have been projected toward and around the moon with the requisite guidance accuracy and the control necessary to maintain proper attitude. So far, however (at time of writing), no soft landing with retro propulsion has been achieved.

An interesting question arises whether the propulsion necessary for slowing down the lunar spacecraft should be that pertaining to the last stage of the earth-launch vehicle. At first sight it seems attractive to use the last stage by burning about one-half of its propellants and leaving the residue for the lunar approach after the last stage has coasted to the moon. No further stage separation is required, and an existing propulsion system is used without the complications of extra engines and redundant elements. However, on further examination, these advantages vanish before the various problems of "flipping" the last stage in space so that the engine points towards the moon, the extra propulsion energy needed to slow down the entire and rather heavy last stage and the need to build into the propulsion system requirements for start-stop and/or throttling—the latter feature needed *only* for the lunar approach.

Furthermore, the normal equations of rocket staging show that the 8,000 feet per second velocity can be eliminated more cheaply by another spacecraft stage with payloads and propulsion designed entirely for the lunar approach. The problem is really one of taking a given multi-stage rocket, firing a next-to-the-last stage, letting it coast for about two days and then once again making up about 8,000 feet per second with another and last stage. It does not really matter whether the velocity vector points backwards or forwards; the velocity increment has to be achieved in some way and can be done more economically by a last stage. Assuming then that the lunar spacecraft contains a propulsion system suitable for lunar landing (and it must be remembered that only a *rocket* system can be used for a lunar slow-down, since no other braking forces are available), what then are the necessary characteristics of a rocket retro system? We assume an ideal system and ignore questions of development, time and availability:

Structural diagram of a two-stage moon probe for a soft landing.
Key: 1. instrument payload; 2. tanks, valves, etc. for second stage propellants; 3. second stage thrust chamber and expansion nozzle; 4. retro and attitude control jets; 5. possible extension of second stage nozzle to achieve a high expansion ratio; 6. skirt around first stage rockets, can act as shock absorber on touchdown; 7. expansion nozzles for the three first stage solid-propellant motors; 8. solid rocket thrust chambers.



a) *Space storability:* During its two-day journey to the moon the propulsion system is exposed to the peculiar conditions of temperature, vacuum and possibly radiation that exist in the space between the earth and moon. It is possible that cryogenics such as LOX-hydrogen could be used, but it seems likely that a non-cryogenic combination such as N_2O_4/hydrazine or nitric acid/hydrazine, or chlorine trifluoride/hydrazine would be more practical. Even if there were no excessive boiling of cryogenics in space there would remain the problem of the low temperature behaviour of valves and seals after many hours of exposure.

I expect that experiments with such rockets as the NASA *Centaur*, burning liquid oxygen and liquid hydrogen, will help to clarify the cryogenics-in-space picture.

b) *Good mass ratio:* For a low payload weight of about 200 lb, the *solid* propellant rocket seems to have a better mass ratio. However, when spacecraft and payload approach a weight of several tons, then the liquid may once again show mass ratio advantages.

c) *Vacuum ignition and system reliability:* The retro propulsion system must of course be able to ignite in the vacuum of space and do so without violent surges and pressure transients. Both hypergolic liquids and most solids have demonstrated good vacuum ignition characteristics, with the solids perhaps having a slight edge. In overall reliability, again, the solid has the obvious advantages of no moving parts, and the only thing that can go wrong is the ignition process. This price, of course, is paid for by lack of versatility, with little or no throttling or re-start capability.

d) *Throttling:* It is mandatory that some control over the propulsion impulse is available. It is inconceivable with the present state of the art that a propulsion radar controller can start and stop the rocket system *exactly*,

* The opinions expressed here are the author's own and do not necessarily reflect those of NASA.

with all total impulse expended *just on landing* on the lunar surface. The propulsion system must have some flexibility to allow for velocity corrections, to say nothing of lateral drift rate and attitude corrections. The *liquid* rocket shines here and is necessary if this feature is to be obtained. It is not too difficult to design a rocket engine system capable of throttling to about 20% of full thrust. Combustion instability and insufficient cooling at reduced thrust (and therefore chamber pressure) ratings are problems which limit the throttling range.

A start-stop or "bang-bang" engine manœuvre is also possible for descent control. But the start and stop combustion (and therefore thrust) transients that would occur would place a tremendous strain on the control system for maintaining attitude. Also, the chance of system breakdown is greatly increased as the hydraulic surges pulse through the feedlines. So it is much more likely that a throttling smooth-control propulsion program will be used.

e) *Good specific impulse:* As in any staged rocket system, the specific impulses of the upper stages must be high if a reasonable economy of vehicle structure and a good payload weight are to be obtained. For a lunar vehicle to be launched by available boosters with a payload weight of 200 lb or so, a mean specific impulse of the retro propulsion system [1] of at least 300 seconds is necessary. The liquid system such as liquid hydrogen/liquid oxygen can do much better than that, of course, but the aforementioned cryogenic problems may preclude their use in early lunar landers. On the other hand, if a specific impulse of 300 seconds only is needed, solid rockets with nozzle expansion ratios of about 60 : 1 could serve the purpose.

f) *Zero "g" start:* Since the spacecraft will be in free fall towards the lunar surface, the propulsion system should have starting capabilities in an environment where liquids can behave unpredictably and pressurization systems could fail. The *solid* is of course outstanding here, with no sloshing or propellant bubbling. On the other hand, if a liquid *had* to be used, small gas jets could produce enough deceleration to achieve a head on the liquids, but of course with the added cost of further complications.

g) *Predictable performance:* It is a further strain on the radio altimeter or propulsion controller to have to tailor the rocket impulse appreciably. It is better if the total impulse necessary can be achieved by the *propulsion system* to within a few lb/seconds. Furthermore, a complete burnout of the propellants leaves none for the actual touchdown and therefore obviates fire danger when liquid propellants are used. A *solid* has the problem of poor shutdown characteristics and the weight penalty of (shut-off) rupture discs, etc. Therefore much ground testing in vacuum chambers and careful quality control would be necessary during the solid rocket's development and manufacture.

h) *Lunar surface blast effects:* This is tied in with the last question. If all total impulse can be achieved at some height above the lunar surface with the spacecraft now falling a short distance to the surface with the shock absorbed by impact bags, crushable legs or gentle gas jets, then a mighty billow of dust clouds may be avoided. The velocities accruing to the spacecraft when falling from even 100 feet above the surface of the moon are not excessive.

On reviewing the above points, it is apparent that a *composite* propulsion system is ideal for a soft lunar lander. And a further look shows that a solid rocket should be used to cancel out about 90% of the approach velocity, with some simple hypergolic or monopropellant liquid system used for trimming the residual velocity, maintaining attitude control and final touchdown manœuvres. It can be argued that a liquid system might as well be used throughout, but as I have stated earlier, the mass ratio advantages of the solid, for the small spacecraft considered here, give it an advantage. It would of course be fine to have a propulsion system with all the desirable characteristics of high performance and versatility of the liquid, combined with the density and reliability advantages of the solid, but such a system has yet to be invented.

Considering the above then, it is possible now to describe the characteristics of a hypothetical propulsion system for landing a net instrument package of about 200 lb on the lunar surface.

Structure

Two stages:	first stage with three solid-propellant motors	
	second stage with one liquid-propellant motor	

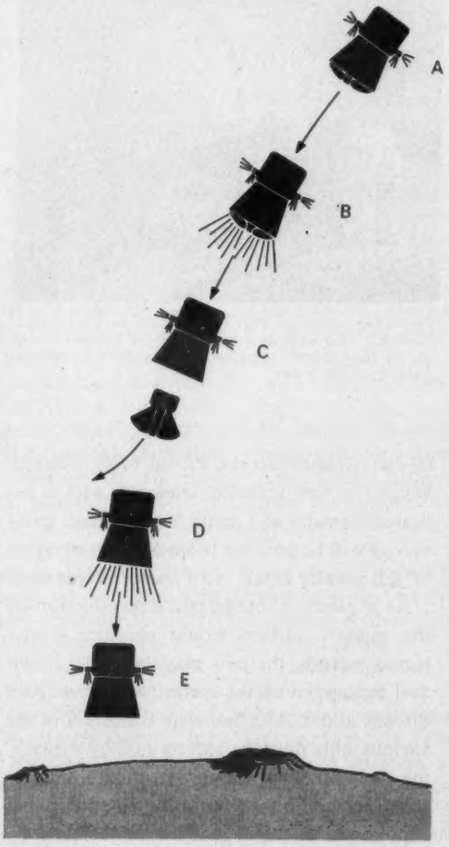
Weights

Instrument payload		200 lb
First stage:	propulsion system, case plus nozzle	18 lb
	propellant	200 lb
Second stage:	tanks plus helium pressure system	4 lb
	main thrust chamber, flow controls, pitch-yaw-roll jets	19 lb
	miscellaneous structure	2 lb
	propellant (monopropellant hydrazine)	40 lb

Performance

Specific impulse, first stage, nozzle expansion ratio 60: 1	280 sec
First stage thrust	6,000 lb
Specific impulse, second stage, nozzle expansion ratio 8) : 1 and chamber pressure 800 psia	320 sec
Second stage thrust	500 lb
Velocity decrement from first stage	7,100 ft/sec
Velocity decrement from second stage	1,000 ft/sec

Possible descent manœuvre for soft lunar landing (two-stage rocket).
The pressure nozzles, set off by command from the radio altimeter, begin to function (A), to bring the vehicle, which is falling at a velocity of almost 8,100 ft/sec towards the moon, into a roughly vertical position. A little later the three solid-propellant rockets in the first stage ignite (B) and decelerate the vehicle to 1,000 ft/sec. After burnout of the first stage, the solid-propellant motors are ejected (C), and the second stage liquid-propellant engine is ignited (D). By burnout of the second stage the entire kinetic energy has been absorbed (E). The moon probe falls freely through the last few feet, but lands at relatively low speed because of the moon's weak field of gravity (one sixth that of the earth); from a height of 200 ft, for example, the speed would be 45 ft/sec.



It is not likely that guidance accuracies will be achieved within the next few years that will allow for an approach to the lunar surface with no velocity components at all. Precise impulse control could be obtained from a multi-leg Doppler system which can give instantaneous altitude and closing rates and even drift rates across the lunar surface. Indeed, a multi-leg system could even yield attitude information. The radio altimeter (which is a function of the Doppler system) must give the ignition signal at a precise time to the main stage propulsion. Then when this has achieved its function, it could be discarded as part of the last stage, and the liquid system now burning would have to decelerate only the spacecraft and liquid propulsion system.

During the last 100 feet or so, we presume propulsion *off*, but attitude control might still be necessary and this could be achieved through a by-pass system with miniature jets and by the venting of pressurizing gases.

Some research must be done in the areas of exhaust gas "ballooning" in a vacuum in order to determine what protection is necessary for spacecraft elements. It might also be possible to earth test the propulsion systems by dropping them from balloons or high flying aircraft over some rocket range. This

[1] Includes average of liquid and solid impulses, if *both* systems are used in the spacecraft.

scheme meets the obvious difficulty of the greater gravitational attraction on earth and the interaction of the atmosphere with the exhaust jets and the spacecraft. Another possibility would be to launch the test lunar spacecraft by a ballistic rocket, letting it separate near the apogee and plunge towards the earth with the retrosystem functioning in the near vacuum above 50 miles.

*

On the basis of theoretical investigations of the kind outlined above, NASA has awarded the Aeronutronic Division of Ford Motor Company a contract for the development of a 300-lb instrument package to be landed on the moon in about two years' time. This is part of a larger spacecraft now being constructed at NASA's Jet Propulsion Laboratory in Pasadena, California. The mushroom-shaped package will be detached from the vehicle at about 20 to 25 miles from the surface of the moon, then slowed down by a retro rocket. The instruments, including a seismometer and temperature-recording devices, will impact on the moon at less than 300 m.p.h. and will be protected by a honeycomb crushable structure designed to absorb severe impact. It is hoped that moon-quakes or meteor impacts recorded by the seismometer will provide new knowledge of the moon's structure. Data will be radioed back to earth for at least a month. The main body of the spacecraft and the capsule will together weigh about 800 lb and will be lifted by an *Atlas-Agena B*. The vehicle will carry a television camera system to photograph the moon and transmit the pictures back to earth. Meanwhile, several commercial firms have received NASA study grants for preliminary work on a soft landing capsule. The name of the project is *Surveyor*, and the booster will be a *Centaur*. The company judged to have the most suitable approach to the problem will be given a contract late this year to design and build a prototype capsule.

Artist's impression of a manned spacecraft after landing on the moon. A dream today, a project tomorrow and perhaps a reality the day after.

Unmanned instrument packages landed on the moon will undoubtedly be able to carry out measurements which cannot be made from the earth even with the most modern tools available to astronomy and astrophysics. Full exploration of the moon, however, will require the presence of man. Before man can first set his foot on the earth's natural satellite, much technical and scientific progress must be made, for there can be no compromise with reliability, performance or safety.

A New Map of the Moon

When man gets to the moon he will find his horizon very limited. He will not even be able to see a 7,500-ft mountain if it is 50 miles or more away from him. Reason: the sharp curvature of the moon's surface. What is more, the moon has relatively few high points which could be used for orientation purposes in certain regions, and finally does not have a sufficiently powerful magnetic field to permit the use of a compass. To find his way around the moon, therefore, he will have to look for other aids. Existing maps of the moon's surface are not accurate enough to serve as guides, either.

The Aero Chart and Information Center, of St. Louis, Missouri, is therefore working, under the guidance of Professor Zdenek Kopal and Dr. J. Ring of the University of Manchester, on a surface map of the moon which is to present even the smallest details in realistic manner. For this work use is at present being made of the photographs taken by the 60-cm refractor on the Pic-du-Midi, France. When the new reflector telescope with a reflector diameter of 1 metre is completed, however, it will be possible to obtain photographs of still greater detail, with shorter exposures.

The observatory on the Pic-du-Midi in the French Pyrenees, now equipped with a 60-cm refractor, will shortly have a new reflector telescope with a reflector diameter of one metre.

As a purely photographic reproduction of the moon's surface would produce a distorted picture, the new map must be drawn as if each point on the surface were seen from directly above. As a first step, the height of the various hills must be ascertained by measuring their shadows, though great care must be taken in the final presentation to ensure that topographical features are not obscured by shadow. Two to three thousand "landmarks" will be drawn in on the basis of existing moon photographs, and the details in between later filled in from some 100,000 cinematographical pictures taken by the new reflector telescope. Even using an electronic computer, it will take about ten years to prepare the first standard map of the moon.

Three mighty circular mountains on the moon: Arzachel, Alphonsus and Ptolemy (from top to bottom).

From Science Fiction to Space Law

Random Notes from the IAF Colloquium on the Law of Outer Space

John Wyndham, a popular writer of science fiction, unfolds a sombre tragedy in one of his latest stories. The scene is a small natural planetoid which serves as an intermediate stop for interplanetary traffic and is manned by a spaceport official from earth and his Martian wife. One day a geologist lands to study the structure of this heavenly body. In a fit of blind jealousy, the official punctures the geologist's space suit, so that he perishes on a scientific excursion. Hereupon the embittered wife discharges the heating battery in her husband's suit, thus coming into possession of a handsome legacy and a no less comfortable widow's pension. A space employment contract, an interplanetary marriage, two murders in outer space, a Martian as heir to an earth-man—in short, everything to make the space lawyer's heart beat faster.

Lest we incur the just wrath of the disciples of this new branch of knowledge, however, we should stress that space lawyers generally keep their imagination under firmer control than writers of science fiction. For they are fully aware that they stand at the beginning of a new development in law, a development which is nevertheless gaining speed like a rocket lifting off from its launch pad. This is understandable in view of the flocks of legal experts who are turning their attention in this direction—a bibliography published as far back as the beginning of 1958 covered some 300 publications with no fewer than 12,000 printed or type-written pages. What is more, certain problems are gradually assuming a burning importance; the possibility of, say, a space vehicle or its wreckage falling on human habitations is not exactly reassuring. And a satellite powered by solar batteries, unabashedly transmitting radio signals for decades as it travels through the heavens without the slightest heed for the ITU frequency regulations, could become a serious nuisance. Finally, the possibility that the moon might suddenly cease to be the common property of all lovers and become the national territory of some power that had landed on it, is anything but attractive.

Law and politics—an ill-matched couple

These and many other problems of space law became acute during the International Geophysical Year, when the Russians put *Sputnik I* into orbit at the beginning of October, 1957, thus heralding the space age. As it happened, the 8th Congress of the International Astronautical Federation was just then sitting in Barcelona with the American lawyer and space law expert Andrew G. Haley in the chair. Fired by the Russian achievement, the IAF launched resolutely into the problems of space law and has since been in the forefront of the organizations striving to bring law and order into space. All this, of course, on a purely private basis for, like the International Law Association and many other scientific bodies, the IAF, which was founded by national astronautical societies, does not speak in the name of governments. The only institution which would be authorized to do so is the committee created by the U.N. Assembly to ensure that space is used for peaceful purposes in the interests of the whole of mankind. But, from the outset, this committee suffered from the same malady which today afflicts law, economics and many other branches of human activity: namely, politics.

When the committee was formed, it consisted of 12 representatives of the Western bloc, 3 of the Eastern bloc and 4 from the "non-committed" nations. Soviet Russia, Czechoslovakia and Poland pressed for parity of numbers between East and West, threatened to leave the committee and finally obtained agreement to the formation of a new committee, to sit for two years, with more members from the Eastern bloc. This committee, in its turn, formed a sub-committee to deal with legal questions. But when the work was well under way, the USSR announced that she was dissatisfied with the choice of chairman. Moreover, as in the ten-power disarmament committee in Geneva, the Russians again began to tie up the question of the peaceful uses of space with the relinquishment of the USA's "terrestrial" bases overseas. In other words, an "international astronautical organization" which would not only ensure that space is used for peaceful purposes but would also create an effective legal system is still a long way off.

In any case, there is at the moment no requirement for an "international civil astronautical organization" on the lines of ICAO. For "private" spaceflight will for a long time remain a pipe-dream. Anything which takes place beyond the atmosphere is exclusively under the stage-management of individual States . . . or, to be more precise, of two States who have no intention of allowing anyone else to interfere in their affairs or lay down the law to them.

Apart from a few paragraphs which could perhaps be taken over from general international law, the development of an international space law can at present be based only on theoretical considerations worked out by the scientists, by the more or less "tolerated" ad hoc United Nations committee and by such private associations as the IAF. Practical steps to create a law of space can be taken only by the individual States, and this law would then be applicable only to nationals of such States. Anyone who ignores this fact when discussing space law is venturing into the realm of science fiction.

Some of the problems

Space . . . law? Here straightaway is the first stumbling block. Is it possible to talk of space law until agreement has been reached on the legal meaning of the word space? The United Nations legal committee takes the view that, in the present state of knowledge, it is impossible to draw a boundary between the airspace—the realm of air law—and space proper—the realm of space law. Nevertheless it has selected a number of space law problems requiring early settlement and stated that in these particular cases no exact distinction is necessary.

This statement would appear to be somewhat rash. The outcome of such generosity in the treatment of preliminary questions was seen in the International Astronautical Federation's colloquium on space law in Stockholm's Apollonia Theatre.

In a paper entitled "High-Altitude Surveillance in International Law," the American lawyer Spencer M. Beresford mentioned incidentally the U-2 flight, remarking that complaints of a violation of Soviet airspace were unjustified since sovereignty over the airspace does not extend to such altitudes.

In answer to protests from the auditorium, the chairman interrupted the speaker, to point out that the U-2 affair had nothing to do with space law, since the flight took place *inside the earth's atmosphere*. There can be little denying that the latter view is probably the correct one. But so long as there is no general agreement upon where air law stops and space law begins, the chairman had no grounds for asking the American delegate to leave the platform. His view of the "space law" nature of this high-altitude flight is as good as any other.

This small incident reveals that a clear definition of the frontiers of space law is of vital importance in connection with the question of national sovereignty. As long as mankind was content to remain within the atmosphere for transport purposes, the jurists could make do with very summary formulations. For example, Article 1 of the Chicago Convention on International Civil Aviation states: "The contracting States recognize that every State has complete and exclusive sovereignty over the airspace above its territory." Admittedly there has been lively debate on the question of the altitude to which this right of sovereignty can be said to extend, but the fact that no final answer has been found has been of minor importance in the past. How far States have been in a position to make use of this theoretical right has become clear in their attempts to prevent illegal entry into their national airspace.

Today, however, the problem has become more delicate. Whereas aviation is not free, but is subject to authorization by the States flown over, it has been generally assumed that space is "res communis," that it belongs to all mankind, can be freely used by all and cannot be annexed.

Up to the present, many conflicting answers have been proposed to the question of how far up States can claim sovereignty, and where "freedom" begins; these range from an altitude of 50 miles, the upper limit of the airspace of interest to aerodynamic flight, to heights of 150,000 miles, 1 million

miles or even more, or in other words to regions in which—in the opinion of certain air law experts—the earth's gravitational force ceases to exert any attraction (?).

Nature itself has shown a supreme disregard for the problem of setting an upper limit on national sovereignty claims. For in the cosmos everything exists in a state of rotary motion, so that a "sovereignty column" projected into space above the territory of individual States would, above a certain altitude, have not a constant, but a continually varying, content. Anyone who follows the changing pattern of the heavens month by month will immediately see this point. But if a legal system has no clearly definable content it cannot be enforced.

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Another question is whether the heavenly bodies in space are common property or "unclaimed" objects which can be appropriated by States. Though the Russians dropped small Soviet stars on the moon, they expressly declared that this should not be interpreted as meaning they laid any claims to sovereignty. This brings us to one of the basic problems in space law, namely whether man is "morally" justified in attempting to set up a legal system to embrace the whole universe and thus bestow on sun, moon and all the stars his earthly treasure of legal wisdom. There may be other living creatures up there who prefer to seek happiness in their own peculiar way. Perhaps it would be more seemly to abandon the high-sounding term "space law" altogether, and speak only of "*space travel law.*"

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To take just one example from the mass of detailed questions, there is the matter of liability for damage caused by space vehicles to third parties on the surface.

The Rome Convention, drawn up under the principles of international air law, covers only damage on the surface caused by aircraft in flight, and cannot be applied to space travel without modification.

At the Stockholm colloquium, Professor J. C. Cooper, one of the highest authorities on air law, proposed the drafting of a similar convention to apply to space travel, under which the State responsible for the launching of a space vehicle should bear the liability for any damage occurring either on the ground or in space (caused by collisions between space vehicles, etc.).

As it would be difficult for private individuals to prove their claims and push through their cases against foreign governments, Professor Cooper suggested that States should create a guarantee fund from which they could pay out compensation to their nationals, claiming reimbursement later from the responsible government.

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This brief article can do no more than offer samples of the varied topics discussed at Stockholm. To look more closely into the many questions raised the colloquium created an Institute for Space Law, with secretariat in Paris and outstanding air and space law experts as its members. These include John C. Cooper (United States), C. Shawcross (United Kingdom), A. G. Haley (United States), E. Pépin (France), to mention only a few. A chairman's seat in one of the working committees was also reserved for the Russians. Will they in fact occupy it?

Book Reviews

Strömungslehre.—By O. Tietjens.—Vol. 1: Hydro- und Aerostatik; Bewegung der idealen Flüssigkeit.—Springer-Verlag, Berlin—Göttingen—Heidelberg, 1960 (German; 536 pages; 496 illustrations; price DM 66.00).

In his foreword the author writes: "I have tried—even at the risk of becoming profuse—to present the material in such a way that on completion of his study the reader will not just have learned something parrot-fashion, but will come away with a thorough understanding of his subject." Nothing could better describe the nature of this book than these words. From his long experience of teaching at two technological institutes (Vienna and Karlsruhe), Professor Tietjens is fully familiar with the difficulties encountered by students—to whom he addresses himself primarily in this work. Main emphasis throughout is on physics, and mathematics are used only to lead step by step to the analytical solution of flow problems. Finally, to render the subject matter even more clearly understandable, the author has included a large number of carefully drawn diagrams of flow lines and illustrated flow processes by photographs to provide a comparison with conditions in real fluids.

A brief introduction on the qualities of real fluids and gases is followed by the fundamentals of hydrostatics and aerostatics with applications to the equilibrium of ships and free balloons. Then follow a few pages on surface tension and capillarity. The first of the chapters on hydrodynamics begins with an explanation of the Euler, Bernoulli and Laplace equations. Many typical solutions of Laplace equations are given and illustrated by flow lines: flow against a flat plate, two and three-dimensional source and sink, potential vortices, source and sink distribution in parallel flow, etc. Two-dimensional potential flow without free surfaces is dealt with in detail in a separate chapter. The introduction of complex functions is again followed by a series of practical examples.

The next chapter is devoted to flows with free surfaces: flow over a dam, flow out of a container, flow in channels, surface waves. Finally, more than one quarter of the book is given over to the study of rotational flow, leading from simple vortices via vortex pairs to surfaces of discontinuity and thence to the distribution of lift over a wing.

A short appendix contains a series of purely mathematical derivations which would have been out of place in the main text. However, these in no way replace a course in mathematics. In fact, full value can be obtained from this book only if the reader has a thorough grounding in higher mathematics. The subject index and index to names are mentioned here merely to complete the picture, although they are not of primary importance in a book which is in no sense a reference work or a short cut to easy learning, but a basic textbook of the best possible kind, thorough, detailed and clearly presented. Any reader who does not understand the theory of ideal fluids after studying this book has only himself to blame ... not the author. Pr.

Propulsion Systems for Space Flight.—By W. R. Corliss.—McGraw-Hill Book Company, Inc., New York—Toronto—London, 1960 (English; 300 pages with numerous illustrations; price £3 7s. 6d.).

How much energy is required to lift one pound of payload from the earth to the moon? How can reactor engineering be applied to astronautics? What is meant by a solar sail? How does an ion beam engine work? Does "negative gravity" occur only in science fiction? Anyone seeking answers to these and similar questions will find them in the present book.

The author discusses the various propulsion methods for space vehicles concisely but with due regard to the basic problems. The reader gets a complete review of the most important physical bases of space travel without lengthy mathematical distractions. Admittedly, quite a number of mathematical formulae are included and illustrated, though they are not explained in detail. The reader is first introduced into the general fundamentals of rocket propulsion; here already the practical significance of the theoretical considerations is brought out. He learns what are the important parameters in the solution of a propulsion problem. Next the methods of producing and converting energy are described in detail: conversion of heat into mechanical and electrical energy, temperature ionization, cooling problems, etc.

In the second part of the book, the author goes into details of the different propulsion systems. Diagrams are used to explain the structure and functioning of power units, graphs and tables illustrate the relationships between the major values. Since chemical rockets have already been dealt with exhaustively in other writings, attention in this book is given chiefly to the "advanced" propulsion systems, in particular nuclear units and electrical power systems.

The book closes with a glance at the future and submits seemingly fantastic solutions such as occur in futuristic novels to realistic scrutiny. For those who wish to penetrate still further into this subject, the appendix lists some two hundred references to other writings.

Although the work is addressed in the first place to the engineer or physicist with a basic knowledge of higher mathematics and physics, it will also be of value to the scientifically-minded layman. Pr.

Radio Aids to Civil Aviation.—Edited by R. F. Hansford.—Heywood & Company Ltd., London, 1960 (English; 623 pages; 260 illustrations; price 126 shillings).

In the words of the editor, this work is designed primarily as a handbook for the planning and development of future systems. In reality, however, it is much more: namely a highly competent reference book on the various radio aids in use today in civil aviation. Well-known experts from Britain's industry and aviation authorities have collaborated on this book, which will fill a long-felt need. As the principles of radio are concentrated in a special chapter at the beginning of the book, these details have been omitted in the description of actual radio aids. The remaining sections deal with aircraft communication systems, en route aids, aids to air traffic control, aids to approach, landing and surface movement, weather radar and radar links, covering these equipments from both the operational and the technical points of view and with special reference to the requirements of civil aviation. Finally, the last chapter looks to the future, in so far as past work enables the trend of development to be discerned. The style is concise and apt, and there are many graphs, circuit diagrams and photographs to help the reader. The ICAO regulations, equipment characteristics and glossary of useful terms given in the appendices increase the value of the book, which should find wide use in aviation circles as a standard work. Eb.

Flugsicherung—Organisation und Betriebsverfahren.—By Karl Möbius. Volume 2 in the series "Die Bücher der Luftfahrtpraxis," edited by Dr.-Ing. K. J. Zetzmann. Second, revised and enlarged edition.—Hanns Reich Verlag, Munich, 1960 (German; 192 pages; 35 illustrations; one map; price DM 11.80).

The rapid development of air traffic control during recent years has necessitated a thorough revision and

considerable enlargement of this book, the first edition of which was published in 1956 (cf. *Interavia* No. 9, 1956, p. 728). Apart from changes in a number of operating procedures and general regulations, the new edition has had to include new sections on air traffic control services for the upper air and on radar control of air transport. The chapters on the certification and operation of radio equipment in aircraft and on the ground, and on the procedures for radio communications have been completely rewritten. The same concise presentation has been retained as in the first edition, and a larger type has been used to make reading still easier. This book has long been a standard reference work in aeronautical circles. Eb.

Hypersonic Flow.—Proceedings of the Eleventh Symposium of the Colston Research Society, held in the University of Bristol, April 6th to 8th, 1959. Edited by A. R. Collar and J. Tinkler. Butterworths Scientific Publications, London, 1960 (English; 432 pages with many illustrations; price £3 10s. 0d.).

The present book reproduces the full text of the papers read at the above-mentioned symposium, together with a summary of the discussion which followed their reading.

If the speed of a flowing gas—or the speed of a body in a gaseous medium—exceeds five times the speed of sound, it is termed hypersonic. The boundary between the "ordinary" supersonic range and the hypersonic range is not nearly so clearly marked as that between subsonic and supersonic speeds. In fact, this boundary is in reality a gradual transition. However, the introduction of a new designation for this speed range is justified because the physical phenomena which occur at Mach numbers above 5 require new theoretical methods and new experimental techniques.

The difficulties encountered in exploring these phenomena are revealed by the fact that almost half of all the papers read at the symposium were devoted to experimental investigations. The theoretical papers dealt with such subjects as boundary layer problems, unsteady flow, the flow field between a blunt body and the bow wave, and Newtonian flow. Finally, a number of papers discussed practical applications, such as the design of hypersonic vehicles, space gliders and air-breathing engines for high Mach numbers.

When a conference is restricted to a narrow field of learning—in particular a new field—the publication of the papers represents much more than a collection of scientific contributions such as is contained in every technical magazine, but gives a more or less complete survey of the state of research in the domain concerned. The present volume must be described as having an encyclopaedic value of this kind. Pr.

The Aeroplane: An Historical Survey of its Origins and Development.—By Charles H. Gibbs-Smith. Her Majesty's Stationery Office, London, 1960 (English; 375 pages; more than 140 photographs; numerous drawings; price £1 15s.).

Written at the invitation of the Science Museum, this monography is in a sense a continuation of the "Historical Survey of Heavier-than-Air Aircraft" (now out of print) by the late M. J. B. Davy, Keeper of the Department of Air Transport at the Museum.

Unlike most aviation historians, Charles Gibbs-Smith has grouped his story not around events and personalities, but primarily around the actual vehicles and their development: aircraft, rockets, parachutes, propellers, control surfaces, engines, etc.

Nevertheless, the men to whose genius these objects owe their existence are by no means neglected, and it is astonishing how much new information the author has unearthed on even the most well-known pioneers—such as Sir George Cayley, to name but one example.

The conscientious, critical but at the same time humorous and gripping account bears testimony to the author's wide-ranging interests. Particularly attractive, for example, is his "interlude" of quotations from writers of many ages, including Lord Byron, Tennyson, Churchill and Jean Cocteau, not to mention Lilienthal, Chanute, the Wright Brothers and Theodore von Karman. One special jewel from this collection is the judge's pronouncement in a witchcraft trial in 1712 that there was "no law against flying." This same open-mindedness, incidentally, has been the guiding spirit in this book by the writer of many works on the history of aviation—a book which will enrich any aviation library. He.

Belastungszeiten von Start- und Landebahnen im Hinblick auf die Anordnung und Notwendigkeit von Schnellabrollwegen.—Edited by the Arbeitsgemeinschaft Deutscher Verkehrsflughäfen, Stuttgart, 1960 (German; 21 pages of text, 14 tables, 29 diagrams; price DM 18.00).

Runways and the taxiways connecting them with the apron are among the most costly installations at any airport, and their dimensions and layout play an important part in determining the airport's handling capacity. As aircraft landing speeds increase, so does also the time each aircraft spends on the runway (since deceleration remains unchanged), which obviously cuts capacity. However, modern aircraft are also much more controllable on the ground, so that some of the problem can be solved by the provision of high-speed turn-offs. Most aircraft with nose-wheel undercarriages can safely negotiate large-radius turns at speeds of up to 50 m.p.h.

If every aircraft landing at an airport could use a turn-off at just the moment when it had reduced speed to the maximum for safety leaving the runway, then the length of time during which the runway was occupied could be reduced to a minimum. The question of cost, however, will in most cases limit the number of these high-speed turn-offs to one in each landing direction. To obtain data on the optimum position for such a turn-off, the speed behaviour of aircraft during landing has been studied by means of a time recorder at three German airports, Frankfurt, Hamburg and Stuttgart. As, at the time of the study (summer 1959), there were too few jet aircraft landing at German airports to provide a representative cross-section, the investigation had to be limited to propeller-driven aircraft. The result is a recommendation that a high-speed turn-off should be installed some 1,300 to 1,500 yards from the runway threshold.

The report contains not only a description of the methods used in the study, but also the complete series of measurements made, classified according to airport, aircraft type and weather conditions.

At a time when many airports are being expanded at great expense, and completely new ones are being built, the present report is particularly welcome. Pr.

High Speed Aerodynamics and Jet Propulsion.—Volume XI, Design and Performance of Gas Turbine Power Plants. Edited by W. R. Hawthorne and W. T. Olson. Princeton University Press, Princeton, New Jersey, 1960 (English; 563 pages; price $15.00).

The title of the eleventh (and last but one) volume in the present series is somewhat misleading, or to be more exact too general; nearly two thirds of the book are devoted exclusively to the design of combustion chambers. Another section deals with materials and blade flutter, while the final chapter discusses the operating behaviour of gas turbines. This distribution is in no way due to an over-estimation of the importance of certain portions of the overall subject matter, but rather to the fact that the editors have deliberately ignored all such material as can be found in any textbook on stationary gas turbines. For this reason, the present volume contains nothing on the strength of rotating bodies, on heat tensions in turbine wheels and casings, or on shafts, bearings, packings or similar mechanical parts. On the other hand, the high and variable combustion chamber stresses in aircraft engines create problems which are of scant significance in stationary motors. In the choice of materials, too, the designer of an aircraft turbine must meet very much more stringent requirements than, for example, his colleague who is designing the turbine for a power station: higher turbine inlet temperatures, frequent starting, periods of operation at less than full load and above all the lowest possible structural weight. There is no need to stress that aircraft engines differ fundamentally from other gas turbines as regards operating conditions. All this is sufficient alone to explain the apparent lack of balance in the allocation of space.

Since a detailed analysis of the contents would fall outside the scope of the present brief review, the chapter titles alone will be given. These in any case give an excellent survey of what the book has to offer. Part 1. Introduction: general considerations; Part 2. Combustion chamber design: requirements and processes; experimental techniques; fuel injection; flame stabilization; mixing processes; fuels for aircraft gas turbine engines; combustion chamber development; Part 3. Mechanical and metallurgical aspects: mechanics of materials for gas turbine applications; flutter problems in gas turbines; Part 4. Turbine power plants: performance. In addition there is a list of references at the end of each chapter, and a general index.

The book is addressed primarily to the designer; principal stress is therefore laid on detailing the results of research to date, a project in which the many diagrams —often comparing theory with results of experiments— afford considerable assistance. The reader's mathematical knowledge need not extend beyond simple differential and integral calculus.

This work needs no special recommendation: anyone who has to do with aircraft gas turbines will put it on the first shelf of his library. Pr.

Surface Effects on Spacecraft Materials.—Edited by Francis J. Clauss.—John Wiley & Sons, Inc., New York, 1960 (English, 404 pages with numerous illustrations and tables; price $11.50).

Under the above title the U.S. Air Force's Air Research and Development Command and Lockheed Aircraft Corporation's Missiles and Space Division organized a joint symposium in May 1959. The present book now reproduces the papers read and the discussion they aroused.

The conditions which a space vehicle meets outside the earth's atmosphere differ from those in the vicinity of the earth's surface to such an extent that many materials behave very differently from their normal practice. The most heavily affected part of a spacecraft is its outer skin. It is not only subjected directly to environmental influences—vacuum, radiation and meteorite impacts—but also has a whole series of tasks to perform, which still further restricts the choice of materials: protection of the payload from excessive radiation and mechanical damage, contribution to the vehicle's rigidity and cooperation in the maintenance of a heat equilibrium. Difficulties begin right away in the exploration of the behaviour of materials, since great technical problems have to be met, for example, in simulating vacuum conditions in the laboratory.

These and similar questions are dealt with in the present volume. The reader will undoubtedly be grateful that the authors have expanded their papers for publication (shortage of time during the symposium had meant cutting them to a minimum) and have included additional diagrams and references. The articles are divided into four subject groups: heat equilibrium of spacecraft; absorption and emissivity of materials; influence of vacuum on the properties of materials and vacuum engineering; and finally the effect of radiation and cosmic dust on the surface of a space vehicle.

As must be expected with so complex a subject, research must arrive at a theoretical basis through experimental techniques. The excellent layout of this book and its clear presentation of a difficult subject will surely create a demand for it outside the still limited group of experts—particularly as the themes discussed are of interest to fields beyond pure astronautics. Pr.

Books received

Erneuerung unserer Städte.—Published by W. Kohlhammer Verlag, Cologne, 1960 (German, 223 pages).

Der Führer ins Nichts.—By H. Buchheim, E. Eucken-Erdsiek, G. Buchheit, H. G. Adler.—Published by G. Grote'sche Verlagsbuchhandlung KG., Rastatt in Baden (German, 88 pages).

Some of the Few.—By John P. M. Reid, Portraits by Cuthbert Orde.—Published by Macdonald & Co. (Publishers) Ltd., London, 1960 (English, 60 pages).

Countdown.—The Story of Cape Canaveral.—By William Roy Shelton.—Published by Little, Brown and Company, Boston, Toronto, 1960 (English, 165 pages).

U.S. Marine Corps Aircraft 1914-1959.—By William T. Larkins.—Published by Aviation History Publications, Concord, Calif., 1959 (English, 203 pages, price $5.00).

Interplanetary Flight.—By Arthur C. Clarke.—Second edition published by Temple Press Books, London, 1960 (English, 144 pages, price 12s. 6d.).

Design for Flight.—The Kurt Tank Story.—By Heinz Conradis.—Published by Macdonald & Co. (Publishers) Ltd., London, 1960 (English, 246 pages, price 21s.).

The Battle of Britain.—By Edward Bishop. Published by George Allen and Unwin Ltd., London, 1960 (English, 235 pages, illustrated, price 21s.).

The Years of the Sky Kings.—By Arch Whitehouse.—Published by Macdonald & Co. (Publishers) Ltd., London, 1960 (English, 334 pages, illustrated, price 25s.).

Fighter Aircraft of the 1914-1918 War.—Published by Harleyford Publications Ltd., Letchworth, Herts., 1960 (English, 224 pages, profusely illustrated, price 45s.).

I Gravitoni.—By A. Prestigiacomo.—Published by Editrice 2000 Torino, 1960 (Italian, 201 pages, price 1200 Lire).

Russische Vliegtuigen.—De Luchtvaart in de Sovjet-Unie. —By Hugo Hooftman.—Published by Verlag ARTI, Alkmaar-Holland, 1960 (Dutch, 85 pages, profusely illustrated.)

Alles over Raketten en Raketvliegtuigen.—By Hugo Hooftman.—Published by La Rivière & Voorhoeve, Zwolle, 1960 (Dutch, 184 pages, illustrated, price f 7.90).

Les Grands Problèmes Techniques de l'Aviation.— J. Lachnitt.—Published by Dunod, Vol. 5 in the series Science et Progrès, 1960 (French, 126 pages, illustrations, price NF 9.—).

Publications scientifiques et techniques du Ministère de l'Air: Distributed by Service de Documentation et d'Information Technique de l'Aéronautique, Paris, 1960:

No. 361: Application de la méthode optique du contraste de phase à l'étude des écoulements gazeux.—By Roger Bouyer.

No. 362: Contribution à l'étude des diffuseurs courts de révolution.—By Osmane Aïdi.

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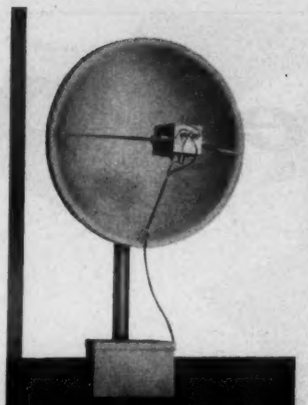

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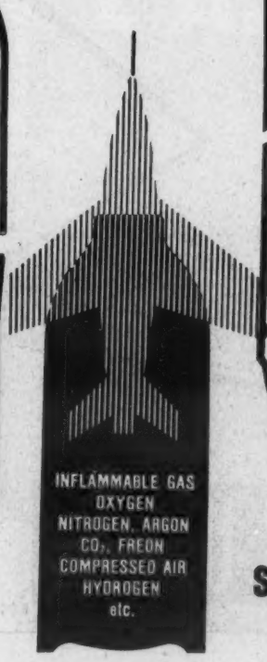

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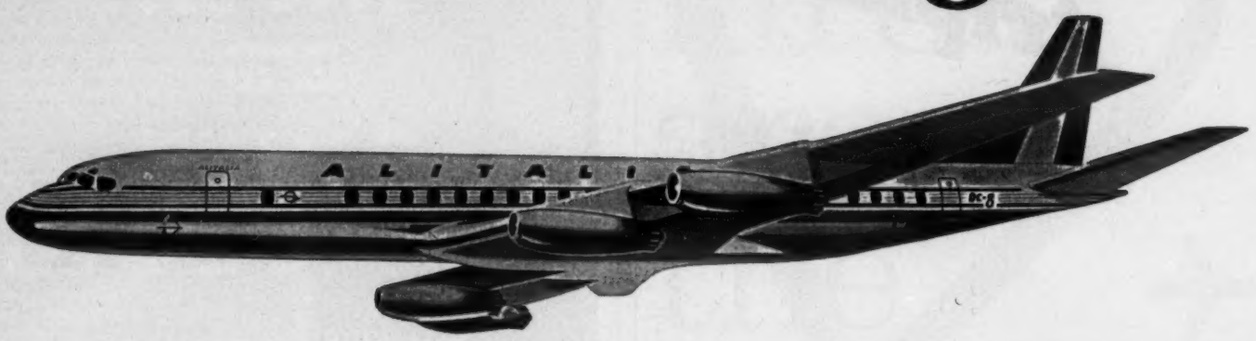

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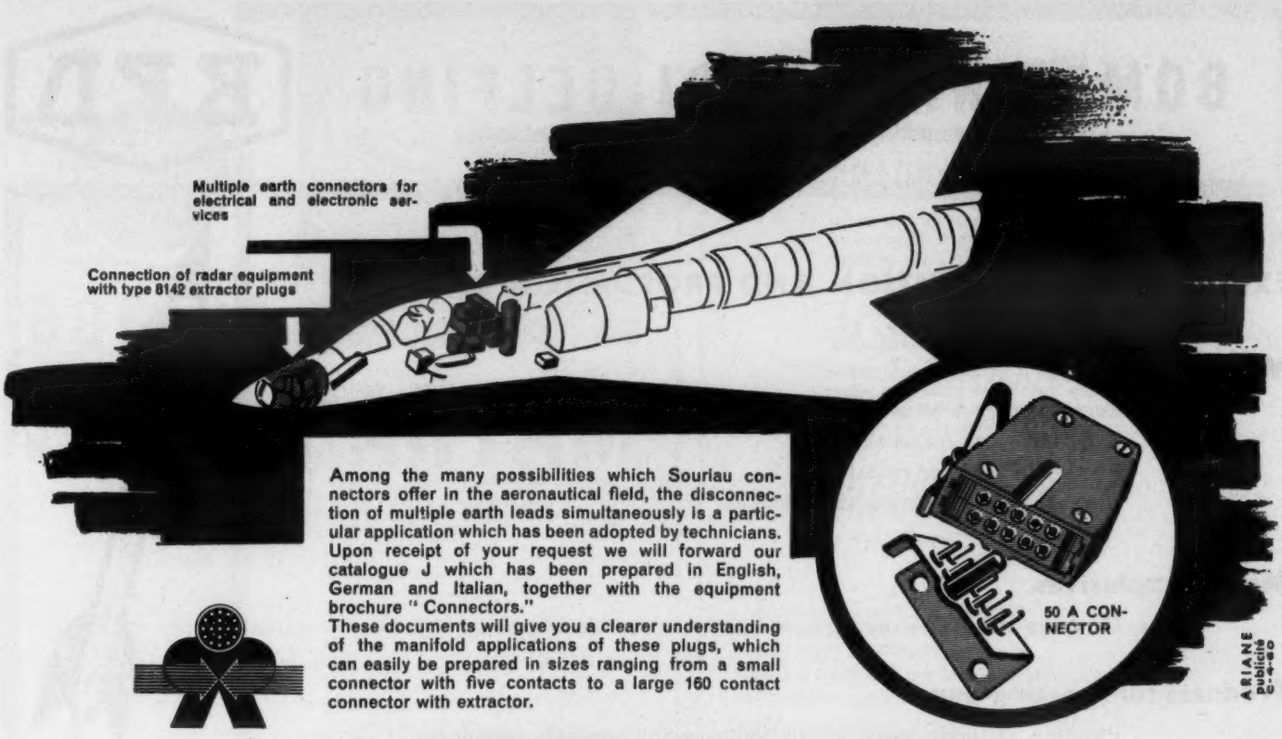
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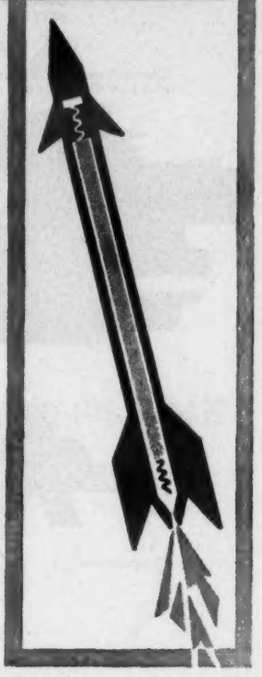

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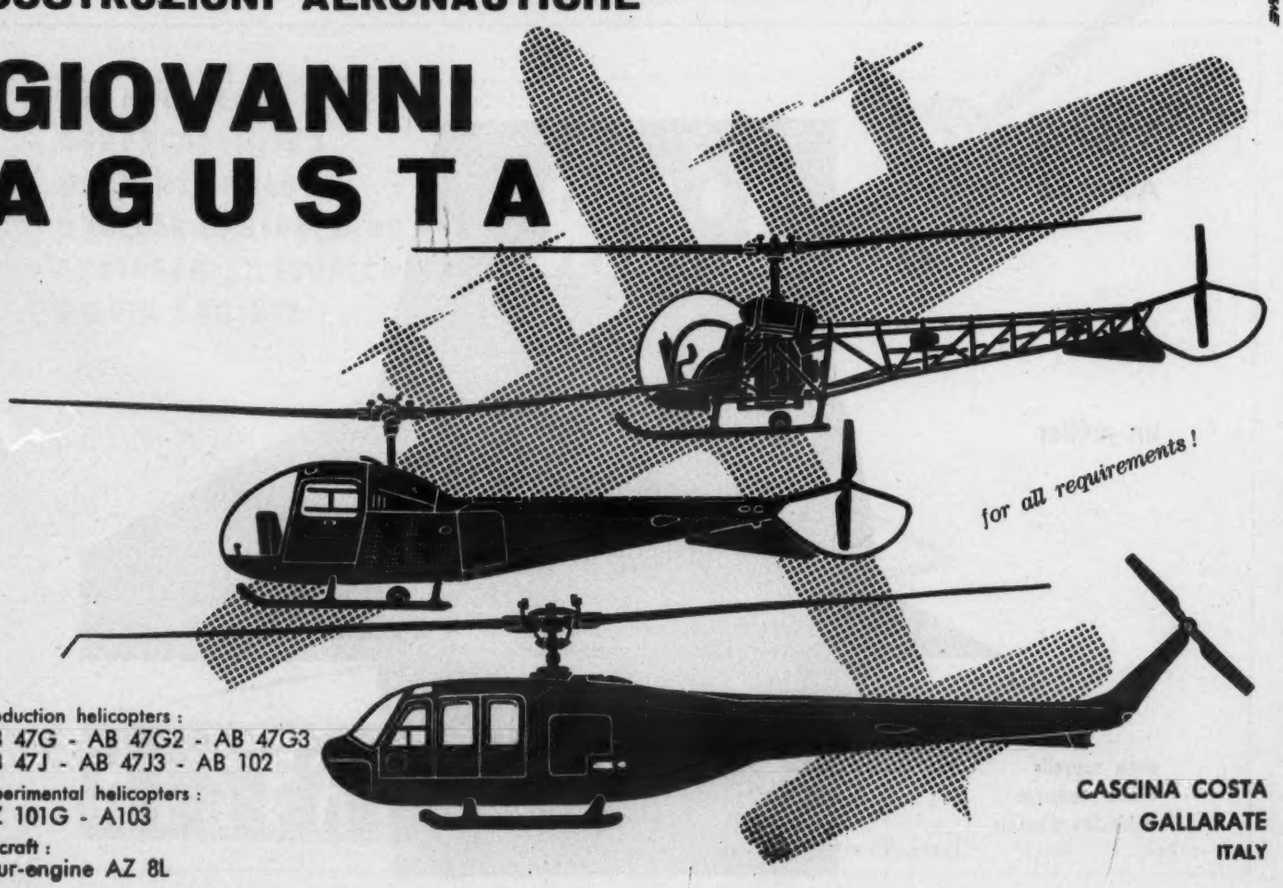

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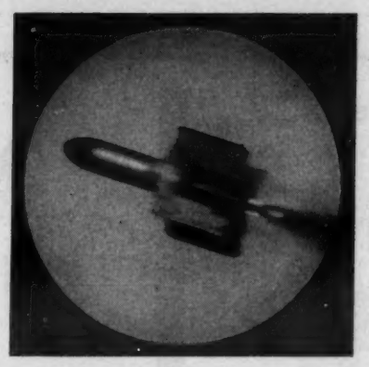

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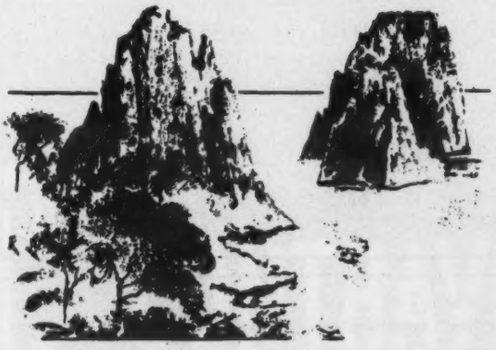

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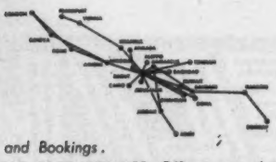

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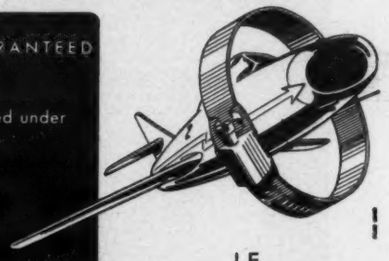

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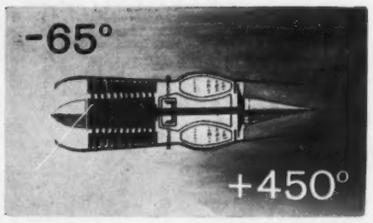

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